and of a short one around each of the locks, are discussed. By the first all the power would be developed at Keokuk, with an average head of 16 feet (the fall is about 18 feet); and by the second plan the head would be about equally divided at the two locks. The backwater sometimes completely floods out the lift of the lower lock, and during a large part of the year reduces it considerably. This may be caused by high water in the river itself, or may happen during a low stage accompanied by a very high stage of the Des Moines river 3 miles below, which has been known to back the water up on the Des Moines rapids nearly 2 miles above Keokuk. On this account the head of water at Keokuk from a hydraulic canal would be subject to a range of at least one-half its amount, and the power would be very much interfered with during high water, while by the second method the portion of the power used at the middle lock would be less liable to obstruction.

To obtain 2,000 theoretical horse-power under a head of 16 feet Mr. Jenny calculates would require a flow of about 1,080 cubic feet per second, which, if a long canal were used, would require the latter to be 85 feet wide on the bottom, 5 feet deep, with side slopes of one-half to one, and a slope of 0.7 foot per mile. It was proposed to tap the government canal about 600 feet above the middle lock, pass under the railroad, and continue down the west side of the railroad for the entire distance, using the canal embankment for the railroad. The hydraulic canal would occupy the part of the government canal where it exceeded 300 feet in width from the east side. The expense would be very heavy, involving the moving of the railroad tracks, large rock excavation, a protecting wall to the embankment along the government canal, and possibly a vertical retaining-wall along the bluff. It could not be less than $150,000.

If the second plan were used the cost would not be more than one-third as great. To obtain the flow of 1,080 cubic feet per second in the upper level of the government canal, Mr. Jenny proposed to excavate a sluice-way around the guard-lock, with a bulkhead at the upper end to control the passage of water; also to run a wing-dam up-stream 600 or 1,000 feet from the head of the retaining-wall of the canal, to deflect a greater body of water into it and to prevent the drawing down of the level in low water by the mills. To obtain this volume of water through the government canal, 250 feet wide by 5 feet deep, would require a current of 0.6 mile per hour, and a declivity in the surface of 6 inches in the distance to the middle lock. In other words, the level would be drawn down 6 inches at that point. If the wing-dam were extended it would give a velocity of 1 mile per hour; then, with 5 feet depth in the canal, there would be 3,400; with 6 feet, 4,000; and with 7 feet, 4,600 theoretical horse-power. It was Mr. Jenny's opinion that a current of 0.6 or even 1 mile per hour would not be objectionable for navigation.

Development on the east side of the river.—There is a chance for a development of water-power on the east, or Illinois, side of the river, opposite Keokuk. There the bluff recedes, leaving a broad bottom-land, across which a slough or old deserted channel of the river passes. By building dikes on each side of the slough, using it for a hydraulic canal, and building a wing-dam 2 or 3 miles up-stream, it would be possible to get a head of 10 feet. There is plenty of room for the utilization of power, and probably it could be done without detriment to navigation in any way; but there is little prospect of carrying out a scheme attended with such expense as this would involve.

There are places on the Illinois bank farther up the rapids where it would be possible to obtain a small head of water by means of wing-dams, and the bluffs recede sufficiently to permit its utilization, but the concentration of fall at the foot of the rapids makes that the place to improve the power, if it is done at all. It seems probable that unless use of the government canal is permitted the expense of development will prevent the utilization of the water-power of Des Moines rapids, at least until the value of water-power is greater in the west.

DISCUSSION OF THE TRIBUTARIES OF THE MISSISSIPPI.

In describing the water-power of these streams it is thought best to begin at the upper waters and describe each one, with its tributaries, in the order in which it is met in passing down the main river. To Mr. Dwight Porter, special agent, were assigned all the western tributaries from the mouth up to the Turkey river, in Iowa, and these will be omitted in this report. Exclusive of the large tributaries—the Ohio, Missouri, Arkansas, and Red rivers—the principal water-power rivers are the Des Moines and Iowa rivers in Mr. Porter's section, and the Illinois, Rock, Wisconsin, Chippewa, Saint Croix, and Minnesota, which are about to be described. With the limited time at disposal it was impossible to investigate exhaustively each small stream, and therefore some discrimination has been necessary in deciding where to devote the time at command. The table of tributaries contains a complete list of all tributaries of the Mississippi of over 500 square miles drainage area, and from it may be gained some idea as to their physical characteristics.

RIVERS ABOVE THE CROW WING.

These are in the undeveloped region of northern Minnesota, and consequently any water-powers they can furnish are now of little value; however, as was stated in describing the main river, these will increase in importance as the state becomes older, the country more thickly settled, and manufactures are in greater demand. That water-

power exists upon these streams we know from the published accounts of explorations and surveys, and that in part at least it can be made available when the demand for it exists, can hardly be doubted. Although the general surface is only rolling or slightly undulating, yet many of these streams have rapids in their courses, just as the Pokegama falls and Grand rapids occur in the main river. The tributaries above the mouth of the Crow Wing river are comparatively small. The Leech Lake river, with its basin of 1,105 square miles, is the largest, and does not fall far short of the entire drainage area of the river above the junction. Succeeding the Leech Lake river in size, the most important tributaries are the Pine, 961 square miles; the Willow, 509 square miles; the Prairie, 491 square miles; the Sandy Lake, 421 square miles; the Swan, 349 square miles; and the Turtle, 300 square miles. Following these are the Rice, the Pinnidiwin, the East branch of the Mississippi, and several others of smaller extent of drainage. These tributaries will vary from 450 theoretical horse-power under a head of 10 feet at their mouths, with the ordinary low flow, down to an inconsiderable amount. They include within their limits probably the most extensive system of natural reservoirs to be found in the entire Mississippi basin, and this fact should add very much to their value as water-power streams. The Leech Lake river is the most conspicuous example. Leech lake, of which it is the outlet, has an area of 176 square miles, and is a great reservoir, equalizing the flow, in which it is aided by numerous smaller bodies of water. The descent of Leech Lake river is slight, as the total fall is only 13.6 feet in about 18 miles. Nevertheless it is probable that an available power exists upon the stream, as the recommendations of the government engineers include a dam and reservoir upon it. With the large storage capacity available, a water-power upon Leech Lake river would be very steady. With the ordinary low flow a head of 10 feet would afford at least 460 theoretical horse-power.

Pine river would afford at its mouth, under a head of 10 feet and with the ordinary low flow, about 325 theoretical horse-power. The headwaters are at the divide, limiting the feeders of Leech lake, and hence the total fall of the river cannot be less than 120 feet. There are rapids in the river, and points at which it is proposed to construct dams for the purpose of making storage reservoirs. Prairie river has rapids in its course where it crosses the same ridge of rock which causes the Pokegama falls. The east branch of the Mississippi is also described by Schoolcraft as having some very strong rapids in its upper portion, as indeed must be the case, for it heads near Itasca lake, and flows in the same general direction as the Itasca branch, which is very rapid in its descent for a large part of its course.

CROW WING RIVER.

This stream, with its drainage area of 3,560 square miles, is the largest tributary of the Mississippi above the Minnesota river. Starting almost at the utmost spring of the Mississippi, it flows 105 miles, in a general southeast direction, and enters the Mississippi about 390 miles below its source. There are a number of lakes within the basin which anywhere else but in Minnesota would be one of its marked characteristics, but there are so many more in the basin of the Red river of the North adjoining on the west, and in the region northward, as to make the Crow Wing basin appear rather scantily supplied in comparison. The principal lake is Gull lake, some 3 by 10 miles in extent. The chief tributaries, from the source down, are the Shell, the Red Eye, the Partridge, the Long Prairie, and the Gull, of which all but the first enter the lower third of the river. On this account over half the basin drains into the lower third of the river only. The section of country tributary to the Crow Wing is very largely a wild, uncultivated region. Lumbering has been the chief business for some 20 years, and as a consequence all the pine has been cut away except about the upper tributaries, where the logging is now done. The southern portion of the basin, drained chiefly by the Long Prairie river, extends somewhat into the settled region of the state, and consequently we find there what is probably the farthest north of all the flouring- or grist-mills of the upper Mississippi basin. It is situated on the Long Prairie river, and uses 54 horse-power under a head of 7 feet. There are two, possibly three, saw-mills in the basin of the Crow Wing, using about 50 horse-power under a head of from 7 to 10 feet, and these, with the grist-mill, embrace all the water-power utilized. No power is taken from the Crow Wing itself. The total fall from the source to the mouth cannot be far from 500 feet, and rapids occur in the stream. Probably there are localities where the power will be utilized in the future. The power at the mouth, with the ordinary low flow, under a head of 10 feet, is about 1,200 horse-power. The Northern Pacific railroad crosses the river at Motley, about 15 miles from the mouth, and for some 10 miles of this distance runs near the stream.

The Long Prairie river enters at Motley from the south. The scheme has been proposed of running a railroad from the Northern Pacific at Motley, southwest through Minnesota, striking the Minnesota river at Lac qui Parle, and then passing into southern Dakota. By this there would be a more direct route for the passage of lumber and grain. It would make Motley an important point, and might lead to the development of a water-power, which from a passing view it would seem possible to improve at that point.

TRIBUTARIES BETWEEN THE CROW WING AND THE MINNESOTA.

For the distance of 136 miles the chief branches of the main stream are the Crow, the Rum, the Sauk, and the Elk rivers, but there are a number of smaller tributaries, each draining from 100 to 300 square miles. Below the Crow Wing river the Mississippi enters a region of country more fully settled, where there is more demand for

water-power, and consequently there are several small custom flouring- and grist-mills and saw-mills, which are run by these smaller tributaries of the Mississippi. Among them may be mentioned the Platte, Watab, Two Rivers, Little Elk, and Clearwater rivers. There are altogether about twenty industries taking their power from the small branches of the Mississippi, which power varies in amount from 15 to 75 horse-power, under a head ranging from 4 to 19 feet. All are flouring- and grist-mills or saw-mills, with the exception of one door and sash factory on the Clearwater river.

SAUK RIVER.

This river has a general southeast course and enters the Mississippi from the west just at the head of Sauk rapids. Near the mouth it is 150 or 200 feet wide. The drainage area is 968 square miles, and includes only a few lakes. The soil through which the river flows is sandy or clayey in nature. The power at the mouth under a head of 10 feet and with the ordinary low flow is estimated in the tables to be 329 theoretical horse-power. The proprietor of a mill at that place stated that about 300 horse-power was obtainable under a head of 8 feet. The shape of the basin is such as to make the river maintain its size for a considerable distance from its mouth.

There are seven industries obtaining power from the Sauk river, all of them flouring- and grist-mills. The highest head used is 18 feet and the smallest is 6 feet. The largest power is 150 horse-power under a head of 12 feet, and the smallest is 12 horse-power under a head of 6 feet. The total power in use is 505 (effective) horse-power.

ELK RIVER.

The Elk river has the peculiarity of rising only 15 miles from the Mississippi and entering it after flowing about 100 miles in a nearly parallel course along the east side. The drainage area is 587 square miles in extent, and a very large part of it is tributary to the Saint Francis, a branch of the Elk river, which enters it from the east about 10 miles above the junction with the Mississippi. The name Saint Francis, according to Schoolcraft, was formerly given to the entire river. At this junction is the town of Elk River, the county seat of Sherburne county. The railroad crosses the Elk river 3 or 4 miles above the mouth, and there the river is some 100 or 150 feet wide, with steep banks of earth about 10 feet high. The estimated power in the tables for the ordinary low flow at the mouth under a head of 10 feet is about 180 theoretical horse-power; above the Saint Francis it is probably not over one-half this amount. The only power used from the Elk river is at a point about 1.5 mile from the mouth, where there are three establishments working under a head of 9 feet. They are rated as follows: A flouring-mill using 200 horse-power, a saw-mill using 100 horse-power, and a furniture factory using 20 horse-power. Of course all three cannot work at full capacity in a low stage of the river. There are other powers which it is possible to develop, of which one is situated near the railroad bridge. There is one establishment upon the Saint Francis river, a saw-mill using 30 horse-power under a head of 9 feet of water.

CROW RIVER.

Five miles below the mouth of the Elk river this stream enters from the west. With its drainage basin of 3,085 square miles it is the largest tributary, with the exception of the Crow Wing, which flows into the Mississippi above the Minnesota river. The basin of the Crow consists chiefly of rolling prairie, interspersed with groves of hard-wood timber and is largely cultivated. There are a number of lakes within its limits, some of them 4 or 5 square miles in extent. About 18 miles from its mouth the Crow river separates into the North fork and South fork, which are by map measurement 96 and 80 miles long, respectively. The area of the basin is nearly equally divided between the two, but the North fork is considered the larger. This impression is very probably due to its draining more lakes than the South fork, and, as it is steadier in its flow, appearing larger in low water. The South fork has a tributary called Buffalo creek, which is 40 or 50 miles long. The Saint Paul, Minneapolis, and Manitoba railroad crosses the South fork at Delano, 3 miles above the junction with the North fork; the stream is there 75 or 100 feet wide at a low stage, with vertical rim-banks of clay, from 5 to 15 feet in height. Below the junction the Crow river averages about 350 feet in width. In the table the Crow river is estimated to give at the mouth, with the ordinary low flow, under a head of 10 feet, 1,050 theoretical horse-power. The greater part of this is supplied by the North fork, but how much it is impossible to say without gaugings. There is only one industry using the power of the South fork, a flouring- and grist-mill at Watertown, about 10 miles from the junction, using some 30 horse-power under a head of 8 feet. The proprietor is obliged to use steam part of the time. There was at one time a mill at Delano, but the dam was carried away and never rebuilt. This dam was made by driving piles into the bed and filling in with brush and stone. The banks at that place are 5 or 6 feet high. On the North fork and the river below the junction there is considerable development of power. Altogether nearly 1,000 effective horse-power is in use under heads varying from 6 to 14 feet. There are 11 flouring- and grist-mills using an aggregate of 655 horse-power. The remainder of the power is nearly all taken by saw-mills.

Power is used on the main river below the junction at four localities. There is a flouring-mill at the mouth; another just below Saint Michael's; a grist-mill and saw-mill at Hanover, and at Rockford are a flouring-mill, saw-mill, woolen-mill, and a cabinet-shop. This is the most completely developed power upon the river, but it is by no means

fully improved. Mr. Florida, the proprietor of the flouring-mill, states that "there is a sheet of water continually running over the dam, say from 4 to 5 inches deep." The head is 8 feet. The flouring-mill uses 95 horse-power, the saw-mill 60, the woolen-mill 45, and the cabinet-shop, 35, making a total of 235 horse power.

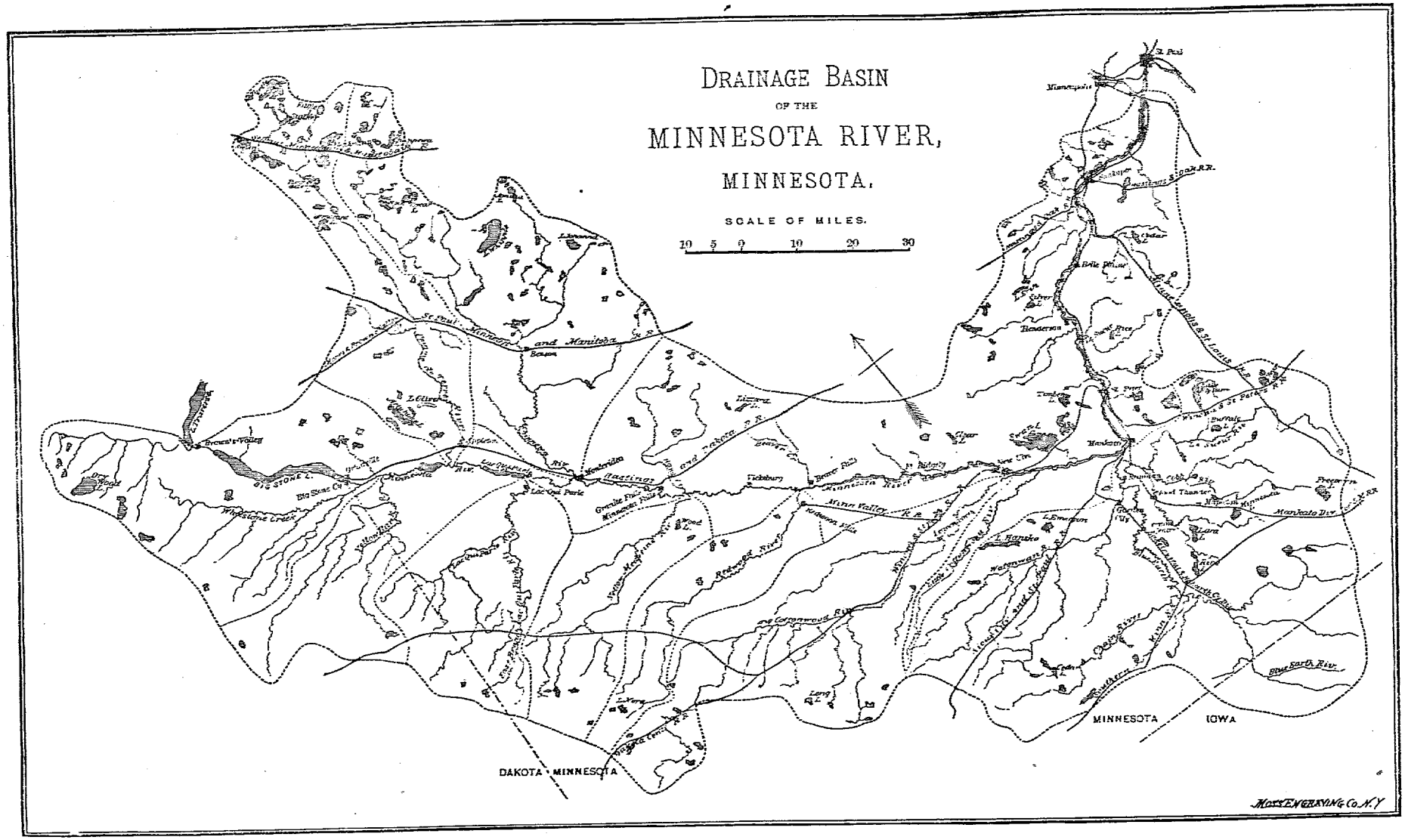
RUM RIVER.

The Rum river has a peculiar drainage basin. Like that of some streams in the state of Iowa it is long and narrow; about 80 miles long and not averaging over 10 miles wide, with a general north-and-south direction. The upper end is Mille Lacs, called by the Indians Michi Sagaigon, meaning "great lakes". It is 186 square miles in extent and the largest sheet of water in the basin of the upper Mississippi. As has been previously pointed out, its drainage area is almost limited to its own surface, as the line of water-shed is in no place more than 6 miles away from the shore of the lake. The Rum river, so named on account of color derived from the swamps and woods, starts from the southwestern part of the lake, and after flowing about 136 miles in a general southerly direction, enters the east side of the Mississippi at Anoka, 7.5 miles below the mouth of the Crow river. The Rum river has been extensively used for lumbering, and from 60,000,000 to 70,000,000 feet of pine are sent down every year, of which the most is sawed before it leaves the river, by mills worked either by water-power or by steam. There are many dams upon the side streams, used for the purpose of holding and flushing logs into the main river. The large body of water at the head of the drainage-basin serves an important part in maintaining the flow of the river during low water. The ordinary low-water discharge into the Mississippi is estimated to be 462 cubic feet per second, giving, under a head of 10 feet, 524 theoretical horse-power. Millers estimate that under this head from 450 to 550 horse-power is practically available. Owing to the large reservoir at the source, the river must maintain its volume in low stages well up toward the head. It is claimed by those familiar with the region that a few miles below the outlet of Mille Lacs a dam could be built with a fall of 6 or 8 feet, which would raise the level of the lake 1 or 2 feet without flooding any valuable land. By properly regulating the flow past this dam a very uniform stage of the river might be maintained. It must, however, be remembered that the drainage area tributary to the lake, outside of its surface, is limited, and that evaporation equals or exceeds 50 per cent. of the rainfall on a water surface in that climate. The owners of water-powers are of course desirous that Mille Lacs should be included in the reservoir system, but the government engineers exclude it on account of its limited drainage area. The Rum river is about 200 feet wide near the mouth, and when visited in the extremely cold winter of 1880–'81 at Anoka, had a strong current about 2 feet deep. The river flows chiefly between clay or sand banks, with usually a bowlder bed at the rapids, but where it crosses the ridge of granite which produces Sauk rapids on the Mississippi, there is a slight fall over rock in place. At only two localities is the power of the Rum river used. The first is at Anoka, some 2,000 feet above the mouth, where there are a flouring-mill and a planing-mill run by it. The head is 8 or 9 feet. The dam, early in 1881, was of brush construction, and leaked very badly. It backs the water about 3 miles up-stream. The other development is at Saint Francis, about 16 miles from the mouth, where a flouring- and a saw-mill use the power under a head of 9 or 10 feet. According to the census returns there is a total of 370 horse-power used from the Rum river, and there is one flouring- and grist-mill upon a tributary called the West Branch, using 50 horse-power under a head of 9 feet.

There are a number of available unutilized powers on the Rum river. It was stated by one familiar with the stream, that from the outlet of Mille Lacs down to Princeton, a distance of from 55 to 65 miles, there are several rapids and available water-power sites, while the banks are high enough to confine the water to the river channel. From Princeton to Saint Francis, a distance of 50 or 55 miles, the river is less rapid, and although there is some fall, yet the banks are low, and it is not so practicable to utilize the power. From Saint Francis down to the level of the Anoka power the river is quite rapid, and there are several available sites. At Oak Grove, about 12 miles above Anoka, is a rapid where the banks are high, and a pile dam could easily be constructed, giving 15 feet head of water. With the ordinary low flow this would afford nearly 800 theoretical horse-power.

MINNESOTA RIVER.

From this river, so called by the Dakotas, the state of Minnesota has received its name. The river was at one time called the Saint Peter's, from a Frenchman who settled at its mouth, and by this title it is described in the reports of early explorations, but a legislative enactment subsequently restored the old Indian name. It is, eminently, *the* river of Minnesota. Starting in Dakota, about 25 miles west of the boundary, the river flows 256 miles southeast and then northeast clear across the southern portion of the state of Minnesota, to join the Mississippi just below the falls of Saint Anthony, between the cities of Minneapolis and Saint Paul. With its drainage area of slightly more than 16,000 square miles, it is only exceeded about 3,600 square miles by the entire basin of the Mississippi above the junction. Although draining such a large extent of country, the Minnesota does not wield a proportionate influence with the other tributaries of the Mississippi. The country from which it runs is not well adapted to maintaining the flow of a large river through the dry season, and hence the Minnesota partakes largely of the characteristics of a prairie stream, a fact pointed out on a previous page.

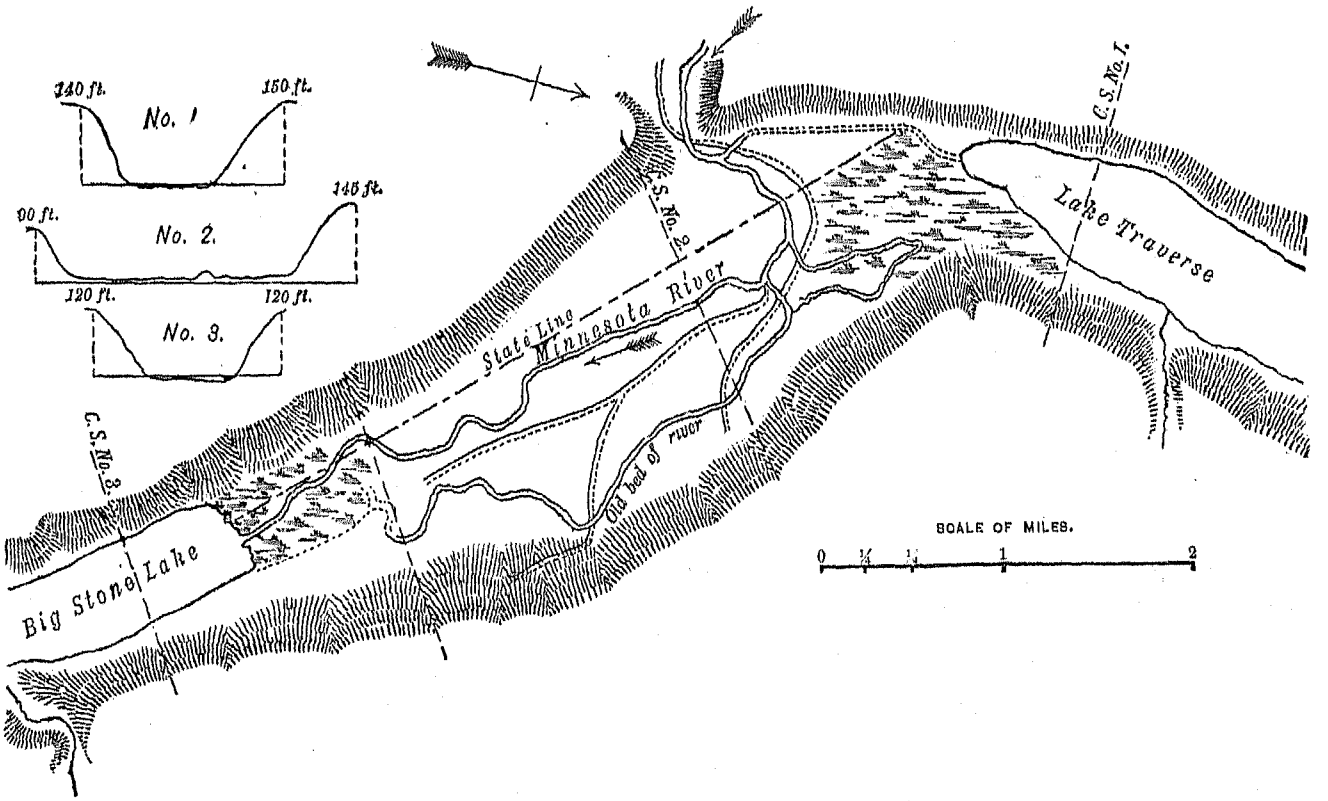

DRAINAGE BASIN
OF THE
MINNESOTA RIVER,
MINNESOTA.
SCALE OF MILES.
10 5 0 10 20 30
DAKOTA
MINNESOTA
MINNESOTA
IOWA
MOSS ENGRAVING Co. N.Y.

General description of the basin.—The drainage basin may be likened, roughly speaking, to a rectangle running southeast through the prairie region of southern Minnesota. On the north a projection forces the line of water-shed far up toward Otter Tail lake, the source of the Red river of the North. On the west and southwest the water-shed runs along the ridge of drift, called the Côteau des Prairies, which extends northwest into Dakota. A southern prolongation of the basin carries the line of water-shed for a short distance into Iowa, and limits the northern drainage of the Des Moines river, and thence the crest-line runs nearly north to the Mississippi. The area included within the limits of the basin embraces very fertile prairie land, and has been, with the country to the eastward, the wheat-raising region of Minnesota, until the Red River valley rose to dispute the claim. The eastern portion of the basin is very fully settled and the region westward is fast coming under cultivation.

On the prairie no trees are seen, and it is only on descending to the river-bottoms that they are found. There cottonwood and several varieties of hard wood, as oak, maple, elm, etc., are met with, but cottonwood is the characteristic growth. In the eastern portion of the basin the timber is more common, and a peculiar growth of hard wood called the Big Woods extends in a belt, 45 miles wide, northwest through the basin. The entire basin is either level prairie or rolling, with troughs cut below the general level, in which the rivers run. The bluffs on either side of these river valleys are generally steep, and it is on them or on the river bottom below that the timber grows. The Chicago and Northwestern, the Chicago, Milwaukee and Saint Paul, and the Saint Paul, Minneapolis and Manitoba railroads have various branches through the basin, from east to west.

GENERAL DESCRIPTION OF THE RIVER.

Starting from the treeless prairie of eastern Dakota, the Minnesota runs southeast some 25 or 30 miles to the boundary between Dakota and the state of Minnesota. Forming the boundary in that region are two peculiar lakes—Big Stone lake, called by the Sioux "Inyan Tonka", from the great masses of granite near by, draining southward into the Mississippi, and lake Traverse, draining northward, by the Bois de Sioux, into Hudson's bay. The first of these lakes is 26 miles and the last 23 miles long; each averages 1 mile or 2 miles in width. The general direction of lake Traverse is northeast and southwest, and of Big Stone lake, northwest and southeast. These two lakes lie really in the same valley, a fact alluded to in the report on the Red river of the North.



Map of Brown's valley, Minnesota. From General Warren's report.

The summit.—The lakes are between 4 and 5 miles apart, and the intervening tract, called Brown's valley, is the dividing ridge separating the waters of Hudson's bay from the drainage of the gulf of Mexico. It is hardly correct to call this the dividing ridge, for in times of flood there is water communication between the lakes. In the report of the chief of engineers for 1874 will be found detailed descriptions of this region, and of the entire Minnesota river, prepared under the direction of General G. K. Warren by Mr. C. E. Davis.

Brown's valley is about 1.5 mile wide, a rich alluvial region, 17 feet above lake Traverse and 22 feet above Big Stone lake. Through the bluff on the western side of this valley, about 1 mile below lake Traverse, the Minnesota has cut its gorge. It runs across the valley to its center, a stream from 15 to 30 feet wide, with banks 10 or 12 feet high, then turns and follows the direction of the valley down to Big Stone lake. A slough, 4 feet deep, 20 feet wide, and 6 feet above the bed of the Minnesota, connects with the swamps at the head of lake Traverse, and when the Minnesota is high there is a water-way, 1.5 foot or 2 feet deep, to lake Traverse.

It has happened that an ice-gorge upon the Red river of the North has backed the water up the valley over the crest, so that it has flowed down into Big Stone lake. The channel between the two lakes is easily navigated in high water by canoes. In 1862 or 1863 the attempt was made to float a small steamboat up the Minnesota river and over into the Red river of the North, but the boat was abandoned about 9 miles below Big Stone lake, where a few years ago the timbers were still to be seen.

The character of the summit between the two systems of drainage suggested the opening of navigation up the Minnesota, and so over into the Red River valley, and it was for this purpose that the survey just mentioned was made in 1868. Nothing has been done in connection with this improvement, which contemplated the construction of canals, dams, and locks along the Minnesota to the Mississippi river.

The bluffs which border Big Stone lake are from 130 to 150 feet high, abrupt, and rising to the prairie level on each side. Below the lake they continue at about the same height and distance apart, forming, with the bottom-land between them, the valley of the Minnesota. This valley continues clear to the Mississippi river, varying from 1 mile to 2 or 3 miles wide, and down it, winding from side to side, runs the Minnesota. At the foot of Big Stone lake the valley is from 1 to 1.5 mile wide; at the mouth of the Minnesota it is less than a mile wide.

Lake Traverse is thought by General G. K. Warren to have been formed by the river filling up the trough at Brown's valley and throwing back the water, while Big Stone lake is due to a similar action by the Whetsone river, which enters the Minnesota below the foot of the lake. When the drainage was limited to the immediate locality the river could not fill its old channel, and hence its crippled energies have been limited in their action to the sorting over of the ancient bed of the valley. Considerable changes have been wrought in this way, and by the side streams, which have worn deep gulches out of the bluffs on either side, spreading the *débris* upon the floor of the valley. The opportunities for the river to sink its new channel very far below the ancient bed are much restricted by the solid granite, which is only thinly covered with drift in places, or else rises in vast water-worn domes and ramparts, sometimes 50 feet or more above the bottom of the valley.

The first granite appears in the valley of the river 1.5 mile below Big Stone lake, and from there to a little below Fort Ridgely, a distance of 110 miles, it characterizes the stream to a greater or less extent. In places the river is rapid over a solid bed of rock; in others, transported material or detached bowlders of the granite itself form bars and ripples in the stream. The great masses of solid rock rising from the soil bear witness to tremendous agencies in their carving. Five miles below Fort Ridgely the solid rock disappears from the bed of the stream, and from there down to the gulf of Mexico the old rock-bed of the valley is covered with the drift, out of which the modern Mississippi and Minnesota are wearing their new beds. Near Saint Paul the rock-bed is about 80 feet below the present level of the Mississippi.

The Minnesota emerges from the foot of Big Stone lake, a small stream about 20 feet wide, flowing between low grassy banks in the swampy meadow which fills the valley at the foot of the lake. The Whetstone river enters from the west, 1.5 mile below Big Stone lake, and as it is a stream about 25 feet wide, it adds considerably to the size of the Minnesota. Below the Whetstone the width of the river is 50 or 60 feet. The Yellow Earth enters from the west, and then the Pomme de Terre from the north. This stream drains lakes away north in the Otter Tail region. Thirty-four miles below Big Stone lake the Lac qui Parle river enters the valley. It is a stream about 60 miles in length, and adds very much to the volume of the main river. By the detritus it has brought into the valley, the Minnesota has been held back in a lake some 6 miles long by 1 mile wide, named Lac qui Parle, "the lake that speaks," from an old Indian tradition. The Indians called the Lac qui Parle river the Cha-Tutpah, meaning the last wooded stream, as, according to Mr. Davis' statement, it is the last river in ascending the Minnesota that has any timber of consequence on its banks. Below the Lac qui Parle river the Minnesota is from 120 to 140 feet wide. About 10 miles down the Chippewa river enters, which, like the Pomme de Terre, drains lakes lying to the north in the Otter Tail region.

Fifty-six miles from Big Stone lake is the head of the rapids, which include Granite falls, Minnesota falls, and the principal available water-power of the Minnesota river. Ten or 12 miles below the town of Granite Falls the Yellow Medicine and the Chetomba rivers enter, the one from the south and the other from the north, and 21 miles farther down stream the Redwood river enters. The three streams, the Lac qui Parle, the Yellow Medicine, and the Redwood, drain nearly all the portion of the basin west of the river in Minnesota. On the north side of the river, after passing the Pomme de Terre and Chippewa rivers, the line of water-shed approaches the stream, and, hence, below that, all tributaries from that direction are small in size. On the south side, however, the water-shed runs about parallel with the river and 40 or 50 miles away, giving drainage sufficient to form streams like the Redwood. These streams greatly increase the size of the river, so that its bed is from 150 to 180 feet wide. Forty

miles below the Redwood is the mouth of the Big Cottonwood, and from 3 to 5 miles below is the Little Cottonwood. The Big Cottonwood is a large stream, 120 feet wide at the mouth, draining over 900 square miles of surface. The width of the Minnesota below the Big Cottonwood averages about 250 feet. Twenty miles below the Big Cottonwood is the great bend of the Minnesota, where it turns through more than 90°, and runs northeast to the Mississippi. At the angle the Blue Earth river enters from the south; it is by far the largest tributary of the Minnesota, draining over 3,000 square miles. With its tributaries radiating on each side, like the arms of a fan, it occupies the entire northern extension of the Minnesota basin, and rises in the prairie of northern Iowa. Below the Blue Earth the Minnesota basin contracts, and nothing but small streams enter the river. The width down to the mouth averages from 280 to 300 feet.

Slope of the river.—The slope of the Minnesota averages 0.89 foot per mile, and in only a few localities does it exceed or even equal 3 feet per mile. For the last 35 miles of the channel the slope is only 0.1 foot per mile. The practically available water-power is located upon the upper portion of the river, and, although it would be possible to develop water-power even where the slope is small, yet the expense attending such an improvement would practically prevent it on the river from the mouth up to near the Redwood river, a distance of about 170 miles. From there up to Big Stone lake are several available sites, which will be mentioned farther on. The river has been declared navigable up to Minnesota falls, a distance of 200 miles, and before the railroad ran up the valley boats used to ply up and down the stream to the Redwood river, and even beyond when the stage of the water would allow, but this was very uncertain and at times sudden in its fluctuations. Being a navigable stream it has been required that all bridges should be constructed with draws over the channel, and, accordingly, expensive structures are built, to be practically unused. There was talk when the river was visited, in the winter of 1880–'81, of endeavoring to have the portion of the river above the Redwood at least declared unnavigable. This would remove all legal restrictions to the construction of dams for purposes of water-power.

Table of data for the Minnesota river.

Station.	Area tributary above station.	Distance from preceding station.	Total distance.	Fall from preceding station.	Total fall.	Ordinary low flow per second.	Theoretical horse-power under a head of 10 feet.
	Sq. miles.	*Miles.*	*Miles.*	*Feet.*	*Feet.*	*Cubic feet.*	*H. P.*
Lake Traverse	.....	.....	.....	.....	.....	.....	.....
Head of Big Stone lake	.....	4.75	4.75	7.71	7.71	.....	.....
Foot of Big Stone lake	500	25.75	30.50	0.00	7.71	50	57
Mouth of Pomme de Terre river	2,000	20.13	50.63	30.12	37.83	180	204
Head of Lac qui Parle	.....	6.19	56.82	8.64	46.47	.....	.....
Foot of Lac qui Parle	4,086	7.46	64.28	0.00	46.47	355	403
Mouth of Chippewa river	6,030	12.25	76.53	14.20	60.67	550	624
Head of rapids, including Granite falls	6,180	10.00	86.53	6.92	67.59	560	635
Foot of Minnesota falls	6,185	5.38	91.91	49.78	117.37	560	635
Mouth of Yellow Medicine river	7,434	4.05	96.56	8.02	125.39	685	777
Mouth of Redwood river	8,422	21.15	117.71	43.45	168.84	785	890
Mouth of Big Cottonwood river	10,447	39.83	157.54	35.75	204.59	900	1,021
Mouth of Blue Earth river	14,510	19.57	177.11	27.02	231.61	2,050	2,325
Belle Plaine	.....	39.93	217.04	57.30	288.91	.....	.....
Foot of Little rapids	.....	9.11	226.15	7.28	296.19	.....	.....
Mouth of Minnesota river	16,027	35.50	261.65	0.40	296.59	2,500	2,836

Flow of the river.—The drainage areas given in this table were measured from the land-office maps; the distances and elevations were obtained from the reports of the chief of engineers, and the amounts of ordinary low flow were estimated by the aid of the tables deduced in treating of the Mississippi basin in general, and from a knowledge of the country drained. Some of the streams in the western portion of the basin of the Minnesota are typical prairie streams, and for them an ordinary low flow per second per square mile of 0.06 cubic foot was taken. In the eastern portion, where there are woods, the flow was taken as high as 0.25 to 0.30 cubic foot per square mile. Between these limits the factor was varied in accordance with the nature of the land drained by the tributaries.

Owing to the uncertain data available for prairie streams, and the great range of fluctuation to which they are subject, it is impossible to determine the ordinary low flow accurately, and the amounts in the table for the Minnesota are given only as a rough approximation.

The lines of equal precipitation on the rainfall chart run nearly parallel with the river above the great bend, and hence, while the tributaries from the north have only about 25 inches of annual precipitation upon their basins, those from the south have from 26 to 30 inches. That this difference exerts any great effect upon the ordinary low flow is not certain. It must be understood that the figures for flow will not apply to the river for severe winter weather, when it dwindles down to a discharge of even 800 cubic feet per second at the mouth, and some of the prairie tributaries are frozen solid at their headwaters. Neither are they applicable to very dry seasons in summer and fall.

The Minnesota probably discharges in high floods 60,000 cubic feet of water per second, when the melting snow and heavy rains on the prairies are pouring rapidly into the valley. The following gaugings at the mouth in 1867 are taken from tables in the chief of engineers' reports:

Date.	Cubic feet per second.	Date.	Cubic feet per second.
June 22	22,819	October 8	2,482
July 6	27,034	October 10	1,696
July 10	22,040	October 17	1,083
July 13	17,272	October 21	1,277
July 17	11,784	October 25	1,824
July 31	17,087	October 30	1,290
August 14	11,410	November 2	1,316
September 4	4,521	November 6	1,826
September 19	2,881	November 14	1,271
September 20	3,797	November 23	1,582
October 2	2,025	November 27	1,342

General G. K. Warren states:

By the time the snow is melted in the upper valley the spring rains set in and last until the latter part of June, when the river is usually at a high-flood stage. From that time it falls rapidly. * * * Sometimes heavy rains occur in August and September, which give several feet rise; but the rains are of short duration, and the river falls so quickly that steamboats do not go up the river on account of the risk of its falling before they return. * * * The river is usually closed by ice from November 20 to April 15, and sometimes much longer. * * * The periodical rains cause a rise from low to high water of 26 feet.

The statement was made by one of the manufacturers at Granite falls that a 10-foot rise at that place was a very high one.

It will be seen from the figures given relative to the flow of the river, and from the description of the country drained, that the Minnesota and most of its tributaries are low-flow streams, depending very largely for maintenance of flow through the year upon a uniform distribution of the rainfall. This they do not get, and hence, unlike the wooded and swampy tributaries at the headwaters of the Mississippi, most of the upper branches of the Minnesota run very low in the dry season, or when severe cold freezes the prairie surface solid may even cease running entirely at their sources. These conditions produce their due effect upon the main stream, and the unsteady character of the flow from so large a portion of the basin of the Minnesota river is detrimental to its water-power.

WATER-POWER SITES ON THE MINNESOTA RIVER.

There are only three establishments using power from the river. They are situated at or near Granite falls, and will be described in course. It is proposed now to give a description, so far as possible from the information obtained, of the location and character of the available water-power sites along the river from Big Stone lake down.

The outlet of Big Stone lake.—The flow of water from Big Stone lake is too small to afford any large power, but it would be possible to run a fair-sized custom mill by the river at that place. The valley is about 1 mile wide between the steep bluffs—a rich alluvial plain of dark sandy loam. At the shore of the lake the banks are swampy and scarcely elevated above the water.

The state line between Minnesota and Dakota passes lengthwise along the valley, and is marked by an iron monument near the lake. Upon the Minnesota bluff is the village of Ortonville, and opposite, on the Dakota bluff, the village of Big Stone City. A wagon-road crosses the valley between the two places, and at Ortonville is the landing for a steamboat which navigates the lake. The Hastings and Dakota division of the Chicago, Milwaukee, and Saint Paul railroad crosses the valley into Dakota a little below the lake, but a side-track runs up to the steamboat landing. The depot is about one-quarter of a mile below the town.

The end of the lake is nearly square instead of pointed, as represented on most of the maps, and is said to be slowly creeping up the valley, being now several hundred feet above where it is represented upon the government plats. From about the center of this end shore of the lake, the Minnesota emerges between sedgy banks scarcely more than 1 foot high. Just below where the wagon-bridge crosses it, the width is about 20 feet, and on January 18, 1881, the water was about 1 foot deep, with an average velocity, roughly measured, of 1.2 foot per second. This would give a flow of 24 cubic feet per second.

The variation in the discharge of the lake is more dependent upon the direction of the wind than upon anything else; a freshet is not so much caused by rain or melting snow as by a strong wind from the northwest, which if it continue for several days will send waves down the lake 3 feet high or more, and raise the level so as to flood the flat. When the wind subsides, the flow of the river is very much diminished, until the lake is replenished. There is a demand for a flouring-mill in the vicinity, which will increase as this region, scarcely opened up before 1879, becomes more settled. There is already a steam mill proposed at Ortonville, which will probably be built, being preferable to an investment in the water-power, but with considerable expense such a power could be developed.

By building an embankment across the valley about 1 mile long and 4 feet high, the waves would not break over it to any considerable extent, and the discharge could be regulated more uniformly. A quarter of a mile down-stream the banks are about 9 feet high, and by building a short dam across the river, with wing-dams connecting with the dam across the valley, it would be possible to obtain a head of 8.5 feet with the lake-level raised about 1.5 foot. It was claimed by those familiar with the matter that five runs of stones could be worked with the greatest ease, and it would be possible to run nearly twice that number. By locating the mill one-half mile farther down, the head would be 9 feet, and one-half mile farther a head of about 10 feet could be obtained. The lake dam would have to be riprapped to protect it from the action of the waves.

The Whetstone river, which enters the Minnesota river 1.5 mile below Big Stone lake, drains a considerable area, and is a large stream in spring. By a dam it is said to be possible to turn it into the lake through an old channel, and it would assist very greatly to increase the body of water. It would be turned off from two farms if this plan were carried out.

Below Big Stone lake.—From the outlet of Big Stone lake down to near Granite falls the average slope of the river is only about 1 foot per mile, and any available powers, if they exist, must be utilized by throwing a dam across at an advantageous point and flooding up-stream for a considerable distance. So far as could be learned from inquiry there is no location in a good condition to be improved without considerable expense, but very likely there are sites that could be developed more readily than that at the foot of Big Stone lake. Just below the mouth of the Pomme de Terre river is a site where it was said that, with considerable expense, a head of 8 feet could be obtained.

Granite falls.—Before any water-power improvements were made upon the Minnesota there was a series of rapids extending for nearly 5.5 miles down the stream, and about at the center of this distance are Granite falls, from which the village near by takes its name. The total descent of these rapids is 49.78 feet, or 9.25 feet per mile. At the foot are Minnesota falls, which will receive notice farther on. The larger part of the descent is at Granite falls, where a fall of about 35 feet is concentrated within a distance of not over 1 mile.

The first improvement found upon these rapids in passing down-stream is at Hickson's mill, 2 miles above Granite falls. With a head of 7 or 8 feet the water is backed up the river about 5 miles. Mr. Hickson has there a small custom-mill, with three runs of stones. From this mill down to Granite falls there is no improvement of the water-power.

Granite Falls is the name given to a place in the river where the water falls about 9 feet over a granite rib, which extends across the stream. The river flows southeast above the falls, close along the left-hand bluffs of the valley, but there it turns and runs nearly south for about 2,000 feet, and then takes another bend to the southeast. This leaves a broad plain, level or slightly rolling, and on this is the village of Granite Falls, the county seat of Yellow Medicine county. Beyond the plain the true valley bluffs rise, and beyond these stretches the fertile prairie.

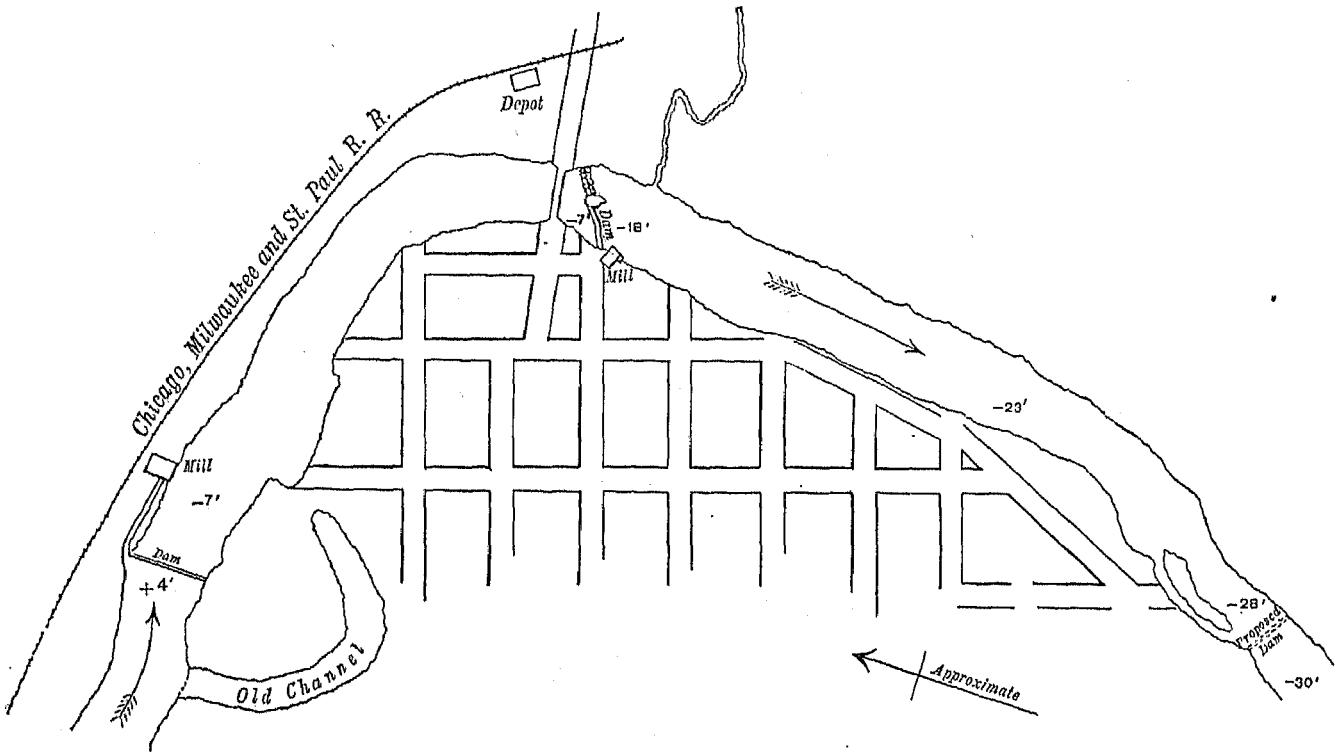
The railroad which runs up the Minnesota to Big Stone lake first enters the valley at Granite Falls, and the station is on the opposite side of the river from the village, to which a highway bridge crosses just above the falls. The granite in place crops out in the valley in large masses, especially west and southwest of the village, where are immense roughly-rounded ridges and knobs rising from the plain, almost deserving of the name of hills. The bluff on the left bank of the river continues in a southeast direction.

The upper bend in the river toward the south is apparently caused by a rocky ridge which runs in that direction. The left bank, which was steep and high, now lowers to a slope of perhaps 20 degrees, rising 15 feet above the water. The right bank below the falls is from 10 to 20 feet high, a steep clay bank leading to the flat.

At the lower bend, where the river turns again to the south, the granite ridge which skirts the western side of the flat and the ridge on the east side of the river meet, and there the river forces its way in a channel about 175 feet wide between solid granite walls from 10 to 20 feet or more in height, carved and rounded by the erosion of the river. The prolongation up-stream of the direction of the channel below the lower bend passes directly along the base of the granite ridge already mentioned, and in this direction are the unmistakable marks of an old river-channel carved through the rocks. This old channel extends up the plain 4 miles and then meets the river once more. In floods it is still used by the surplus waters of the river, and through it the steamboat passed which has been mentioned as attempting to cross over into the Red river of the North.

Mills at Granite Falls.—The only power used in the vicinity of Granite Falls is taken by two flouring-mills. One is about half a mile above the falls. An old log and brush dam gives a head of 4 feet, and a race running along the left bank 600 feet increases the head to 11 feet. The mill is a small one of only three runs of stones. The race is about 10 feet wide; the pond backs up to within about 2 feet of the level of the tail-race of Hickson's mill. It is the intention of the proprietor to build a substantial masonry dam and erect a large merchant flouring-mill. It would be possible to increase the head nearly 2 feet, and as the right bank is very low at the dam, this would necessitate the building of a short embankment. The bed of the river at the dam is of clay and bowlders, and the banks are of clay. The other mill is situated directly at the falls, at a situation admirable for the construction of a dam. The granite rib which forms the falls extends part way out from the left bank, above the water-surface, and it was only necessary to build the dam across the remaining space on the solid rock bed.

By backing the water up to the tail-race of the mill above a head of 11 feet is obtained directly at the dam. It is utilized by a flouring-mill on the right bank, which takes 125 horse-power. During the severe winter of 1880–'81 this mill ran five runs of stones, by filling the pond during the night and gradually drawing it down during the day. This is the last mill on the Minnesota river.



Minnesota river at Granite Falls, Minnesota. (The levels are approximate.)

From the description given it will be seen that with the present dams all the fall is improved from the head of the rapids to the foot of the falls.

Below the falls the river is rapid to beyond the lower bend. A line of levels was run on the ice from the lower bend up to the tail-race of the mill, and the fall was estimated to be between 10 and 15 feet.

The power is owned partly by the Messrs. Pillsbury, who are so largely interested in the mills at Minneapolis. There is some legal difficulty in the way of its development, but this can be settled, and it has been proposed to build a dam at a point a few hundred feet above the lower bend. The left bank is low, and would probably be flooded to some extent.

It was proposed some time ago, before the present interests were established, to run a race from near Hickson's dam down the flat to near the foot of the old channel, and there make a basin, along which to station mills. By this means a head of at least 30 feet could be obtained.

The river is not so rapid from the lower bend down to Minnesota falls, 2 miles below Granite falls, but at one point, about half-way between, is an island, past which the descent is more concentrated, and there a dam could be constructed, but with the power at Minnesota falls and above fully improved there would not be sufficient fall left at this point to be of value.

Minnesota falls.—This is a concentration of the descent over granite rock at the foot of the 5.5 miles of rapid water. The village of Minnesota Falls is upon the right bank at this place, and it was the expectation that it would be the principal town of the region, but the construction of the railroad determined that for Granite Falls. There is a log and stone dam on solid granite at this point, and just below are the ruins of a flouring-mill, which was burnt shortly after its erection.

The head available at the mill-site with the present dam is about 10 feet. It is the intention of the proprietors to rebuild, and by means of raising the dam so as to flood out rapids above, also blasting out a tail-race in the rapids below the mill, a head of 16 or 17 feet can be obtained.

Below Minnesota falls.—As the river is declared a navigable stream below this place, riparian owners would have no right to improve any water-powers that might exist. There are several locations, however, which are otherwise available, and in course of time it may be that they will be developed.

The river is not so rapid below Minnesota falls as in the stretch of rapids above, yet in the distance of 21 miles from the Yellow Medicine, which enters 4.5 miles below, to the Redwood river, the average slope is 2.05 feet per

mile, and at least three places afford opportunities for obtaining water-power. These are Patterson's rapids, Sacred Heart island, and a point about 2 miles above the mouth of Redwood river. There is also a location 1 or 2 miles below the mouth of the Redwood river. So far as could be ascertained these are the only water-power sites from Minnesota falls down to the mouth of the river which offer any good opportunities for improvement; there may be others, but no knowledge could be gained concerning them. The exceedingly severe winter weather of January, 1881, prevented any detailed examination of the river.

Patterson's rapids are about 13 miles above the mouth of the Redwood, and Sacred Heart island is 3 miles below the rapids, and at both places a head of about 8 feet can be obtained. The bed and banks are solid granite. At Patterson's rapids the plan of development would probably be to use an old deserted channel about 1.5 mile long, part as a head-race and the lower portion for a tail-race, placing the mills between. The property is owned by the proprietors of the Minnesota Falls power. At Sacred Heart island the location is very fine for building a dam across each channel to the island.

The place 2 miles above the Redwood is described as affording a head of 16 feet by the building of a dam about 200 feet long. The bed and banks are solid rock. The site below the Redwood river would give a head of 16 feet. The dam would be built on a rock foundation, and the water carried in a race some distance down stream.

Probably both of these last two powers could not be developed without interfering with each other.

Three miles above New Ulm are rapids, and also below the town are some powers, but it is the opinion of those familiar with the river that the expense of improvement would outweigh all value of the power. Then from the height to which floods rise in the river there would necessarily be times when back-water would destroy the head. This disadvantage would be met, although perhaps in a limited degree, upon any developed water-power on the Minnesota river. The statement made at Granite Falls, that a 10-foot rise was an unusual one there, would probably scarcely apply to any other portion of the river's course, because there the steep descent permits the water to flow off rapidly.

TRIBUTARIES OF THE MINNESOTA.

The principal tributaries for power are the Blue Earth and its branches, the Redwood, the Big Cottonwood, the Chippewa, and the Pomme de Terre. The prairie streams are very uncertain, and little dependence can be placed upon them except during the wet months of the year. Then they run full; but, with no woods and very little swamp or lake area to hold the water, they afterward dwindle away to small size. When the cold of winter freezes the prairie, they may be nothing but a mass of solid ice at their headwaters, receiving the flow from a few living springs farther down.

Nevertheless, these streams are made use of to drive the machinery of flouring-mills of small size, sufficient to do the local grinding, and on some of the larger ones less subject to the prairie influences there are mills doing a considerable business.

These tributaries of the Minnesota have a rapid descent, and are not lacking in power so far as that factor is concerned. Many of them enter the Minnesota valley with a slope of 10 feet or more per mile. They have cut their ravines deep below the general level of the prairie, and come out upon the floor of the valley 100 or 200 feet below; hence, judging from this descent, the smaller streams at least must have many rapid places in their courses.

WHETSTONE RIVER.

Thus the Whetstone river, which enters from the west just below Big Stone lake, has a mill, the only one upon it, at which, by tunneling through a neck of land, a head of 32 feet is obtained, and by raising the dam it could be increased to 40 feet. This mill has two runs of stones, but about three could be operated most of the time. This river is very small in low water.

LAC QUI PARLE RIVER.

The Lac qui Parle is similar in this respect, almost drying up at times.

Small streams.—Before proceeding to the description of the more important tributaries, it should be stated that there are several small streams not mentioned at all which, unsteady though they may be, yet can be used in the future to furnish power for small mills. Notable among these is Beaver creek, which enters from the north 2 or 3 miles below the Redwood river. There are two mills upon it; one noted in the census returns as using 30-horse power under a head of 17 feet, also using steam; the other using 12-horse power under a head of 30 feet.

POMME DE TERRE RIVER.

This stream flows almost directly south. Rising very near Otter Tail lake, the source of the Red river of the North, it drains several lakes, chief among which are Turtle, Christina, and Pelican lakes. On account of this tribute which the lake region of Minnesota offers to the Minnesota basin, the Pomme de Terre is more steady in its flow than the true prairie tributaries, especially in summer. During cold winters the lakes are not always sufficient to prevent its falling away, but the mills rarely have to stop on that account. The Pomme de Terre is about 100 miles long, but as the basin is long and narrow, no tributaries of importance enter it. Its valley, as well

as that of the Chippewa, which flows parallel to it on the east, is from one-quarter to one-half a mile wide, with bluffs 75 or 100 feet high most of the way. These valleys are considered by Professor N. H. Winchell to have been probably lines of drainage from the retreating ice-fields of the north leading into the main Minnesota trough. Like the modern Minnesota, the Pomme de Terre and the Chippewa are almost lost in their large valleys.

The railroad crosses the river about 10 miles from the source, and thence down to the mouth the total fall is not far from 250 feet. From where the railroad crosses it about 30 miles above the mouth, there is a descent of 100 feet. The average slope of about 3 feet per mile affords available powers. The banks and bed of the river are sandy gravel and clay, and the banks are generally high enough to prevent flowage from dams.

There are five improved powers upon the Pomme de Terre. The first is at Appleton, on the railroad, 2.5 miles above the mouth of the river. A flouring-mill there uses four runs of stones under a head of 10 feet, and part of the year power could easily be obtained for six runs.

The dam, about 75 feet long, is built on the clay bed of the river, of logs, brush, and stone, planked over. Just below the mill is a bend in the river, with a steep eroded bluff, some 30 feet high. Over this the snow has been known to drift level with the top and flood the water back upon the mill. Two miles above is a mill using about 40-horse power under a head of 10 feet. There advantage has been taken of a bend in the river, a canal cut across the neck, and about half the flow carried through it. About 20 miles from the mouth is a mill with a head of 8 feet and rated at 24 horse-power. Above this is a mill rated in the census returns at 70 horse-power under a head of 10 feet; and still another above, in Otter Tail county, at 70 horse-power under a head of 18 feet.

There are some undeveloped water-power sites of which information could be secured, and undoubtedly many others exist. From Appleton down to its mouth the river is rapid, and in that distance of 2.5 miles at least one fine power can be obtained.

By building a short dam about a quarter of a mile below the railroad track and carrying the water in a race across a neck of land, a head of 17 feet can easily be used. This power is considered by the millers equivalent to eight runs of stones. Two sites were mentioned, about 6 and 12 miles, respectively, above Appleton, where a head of 8 or 10 feet is available; and then, again, near the town of Elbow Lake, on the upper portion of the stream, there are two sites, one of which would afford a head of 14 feet and the other 8 feet. A miller familiar with the stream considered that a head of 14 feet in that section would afford sufficient power for four runs of stones.

CHIPPEWA RIVER.

This stream rises near the region drained by the headwaters of the Pomme de Terre, and like it drains several lakes, the largest being lake Whipple, about 7 miles long by 1.5 mile wide.

The basin is rather larger than that of the Pomme de Terre, spreading out toward the east so as to afford a tributary some 35 miles long, called the East branch, which enters the main stream at Benton, about 30 miles from the mouth. The Chippewa is somewhat similar to the Pomme de Terre, but appears to be rather more unsteady in its flow, probably because it drains a larger area of prairie country, not supplied with lakes.

The nature of the valley and of the bed and banks is like that of the Pomme de Terre. According to the railroad levels, the total fall from about 10 miles below the source to the mouth is slightly more than 400 feet, giving an average slope of about 5 feet per mile. There are several unimproved powers.

According to the census returns there are five mills upon the main stream and three upon the East branch.

In the first 12 miles above the mouth of the river are two flouring-mills, one using 22 horse-power under a head of 8 feet, and the other 36 horse-power under a head of 7 feet.

Above the junction of the East branch are the remaining three mills, in the following order, up-stream: 33 horse-power under a head of 15 feet, 60 horse-power under a head of 21 feet, and 26 horse-power under a head of 15 feet; the latter is near the headwaters. The mills upon the East branch are situated at Swift falls and at Chippewa falls, above. At the former is a flouring-mill, using 35 horse-power under a head of 12 feet, and at the latter are a flouring-mill and a saw-mill, using, respectively, 30 and 23 horse-power under a head of 18 feet of water.

YELLOW MEDICINE RIVER.

This is the first tributary on the west or right bank of the Minnesota of any size below the Lac qui Parle river. It runs back 50 or 60 miles into the prairie, and drains about 600 square miles. Near its mouth the river is from 30 to 50 feet wide, with steep clay and gravel rim-banks rising from 10 to 20 feet. It is an unsteady stream, pouring a large volume of water into the Minnesota when in flood. About 5 miles back from the Minnesota valley is the only mill upon the stream, a flouring-mill of 2 or 3 runs, using a head of 20 feet of water. Below the mill the stream is more rapid than above, for it there has a swift descent through its gorge to the Minnesota valley. In the valley itself it has an average slope of nearly 5 feet per mile. There are some unimproved water-power sites.

REDWOOD RIVER.

The Redwood has the same general course as the Yellow Medicine, and drains pretty much the same character of country, but is somewhat larger. Its total length is about 70 miles. At the headwaters is lake Benton, given on the land-office maps as about 5 miles long and from 1 to 1.5 mile wide. This lake serves to some extent to regulate

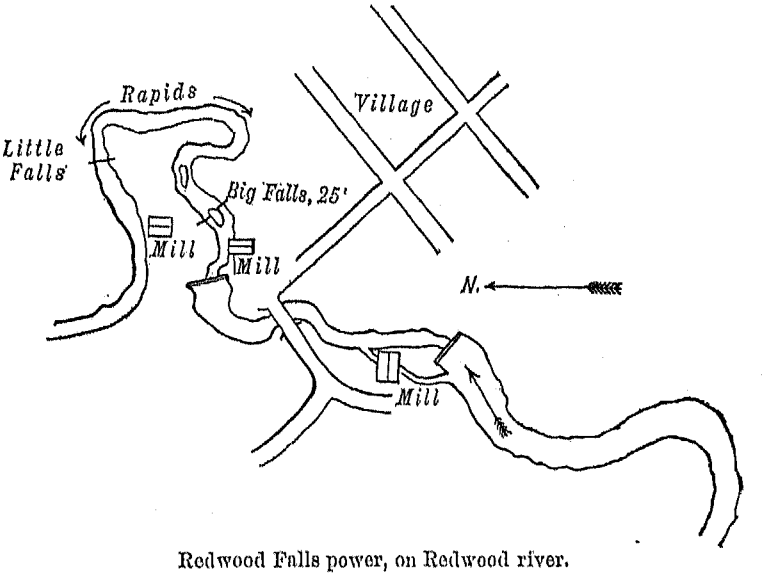
the flow of the river in low seasons, and it is claimed that by building a dam its usefulness in this respect could be increased. The volume of the river is small during severe winter weather, and there seems no reason to believe that as regards regularity of flow it is very much superior to the Yellow Medicine. It is considered good near its mouth throughout the year for three runs of stones under a head of 20 feet, and part of the time much more power can be obtained. There are no important tributaries of the Redwood river. There are altogether seven mills, all flouring- and grist-mills, upon the river—one three-quarters of a mile from the mouth; three at Redwood falls, 2.5 miles above the mouth; one at Marshall, a little more than half-way up the river; another a few miles above; and the last at Lynd, about 6 miles above Marshall.

The first mill on the river has two runs of stones, under a head of 20 feet.

Redwood falls.—It is from these falls that the river gains its chief interest as a water-power stream. In seeking the level of the Minnesota valley the river falls 102 feet within a distance of less than a mile. Its channel runs deep through solid granite, rising in vertical cliffs many feet above the water, or sloping off in steep earth-covered bluffs. Along the cliffs are the wild red cedars, which have probably given the name to the river.

Big falls, with a vertical pitch of 25 feet, and Little falls below, add much to the scenery of this beautiful and unexpected gorge in the prairie. The channel of the river is very winding, and advantage can be taken of this in developing the power.

The village of Redwood Falls, the county seat of the county of that name, is situated upon the right bank of the river, and has railroad connection with the Chicago and Northwestern lines.



Redwood Falls power, on Redwood river.

The upper mill has three runs of stones, working under a head of 20 feet. The pond backs up-stream about 2 miles. The race is cut out of the granite, and the mill has been set down into the rock. This granite is somewhat soft near the surface, and not difficult to remove. The bridge, a substantial structure, spans the river from cliff to cliff about 50 feet above the water. The second mill is situated a short distance below the bridge, and uses two runs of stones, under a head of 20 feet. The pond backs up within 1 or 2 feet of the level in the wheel-pit of the upper mill. The lower mill has a head of 10 feet, and employs two runs of stones. The mill itself is situated on the bluff 100 feet above the river, and the power is transmitted to it by wire rope.

Undeveloped power.—Between the last two mills is an extensive bend in the river and about 65 feet of unutilized fall. In this distance are both of the falls mentioned above and a long stretch of rapids. At Big falls, which is just below the middle mill, is the best power upon the river. Twenty years ago the government had a saw-mill there for the Indian agency, but this is now in ruins. The late owner had intentions of improving the power, but since his death nothing has been done. By cutting a race about 130 feet long across a small bend a head of 40 feet can be obtained. If a tunnel were driven through the neck of land across the large bend, coming out below the lower mill, a head of 75 feet could be gained, but this would of course interfere with the other powers. A dam could be thrown across the river at Little falls, flooding up on the rapids, and a head of 25 or 30 feet could be obtained without interfering with the Big falls power. It is easy to see that only a small portion of the power at Redwood falls is now developed.

Redwood river above the falls.—The three mills above are all flouring-mills. That at Lynd has a head of 22 feet and uses 50 horse-power. The other two use 34 and 18 horse-power, under heads of 11 and 12 feet, respectively.

There are several unimproved sites on the Redwood river in addition to those at Redwood falls. From below the falls to the lowest mill on the river there are several locations. According to the statement of one of the millers, there are two locations affording a head of 20 feet each, and two more of 15 feet each. The banks are high, but consist of clay and gravel. The only unimproved powers of any importance between Redwood falls and Marshall are these: Three miles above the upper mill is a site where a fall of 20 feet is available, and 10 miles above the mill is a locality where, in the winter of 1880–'81, a dam was being constructed to give a head of 12 feet. About 20 miles above Redwood falls is a portion of the river with a rock bed, where a head of 10 feet can be obtained. So far as could be learned these are the only unimproved powers of any importance below Marshall. Any unimproved powers above Lynd must necessarily be small, because of the reduced size of the river.

BIG COTTONWOOD RIVER.

This stream drains an area of nearly 1,000 square miles, and when swollen by melting snow or rain is of large size, but in dry seasons or severe winters it is very much reduced, so that under a head of 10 feet not more than three runs of stones can be used at all times near the mouth; for a large part of the year, however, much more power can be obtained. The bed and banks of the river are of clay and gravel. There are, according to the census returns, only three mills upon the Big Cottonwood, and all are on the lower quarter of its course. They work under a head of 10 feet, and use 12, 56, and 15 horse-power, respectively. All but one of them have two runs of stones each; the exception is a mill at Iberia, which has only one run. There is a number of unimproved sites. One was mentioned, 4 or 5 miles from the mouth, and another at the village of Burns, about 30 miles from the mouth. By building a dam at that place, and carrying the water in a race across a neck of land, a head of 10 feet could be obtained. This would probably give power for two or three runs of stones.

BLUE EARTH RIVER.

The drainage system of the Blue Earth is rather peculiar. Two miles above the mouth the Le Sueur river enters from the east, and 10 miles above the mouth the Watonwan carries into the Blue Earth the drainage from the western portion of the basin. The entire area is divided somewhat equally among these two tributaries of the main river. The Maple and the Cobb rivers are the two streams which drain most of the Le Sueur basin, which is largely within the tract of timber known as the Big Woods, and the soil rather sandy and light, while the remainder of the Blue Earth basin has a heavier soil and has more of the prairie characteristics.

The Blue Earth above the junction with the Le Sueur is slightly larger than the latter stream, and below the Le Sueur averages 150 or 200 feet wide.

The Le Sueur averages about 75 feet wide and the Watonwan about 50 feet. As regards uniformity of flow the Le Sueur stands first in the entire Minnesota basin; it drains the wooded region and also several lakes and swamps. The upper Blue Earth and the Watonwan appear to be about average streams in this respect, not perhaps so unsteady as the prairie streams westward.

The main river.—The greatest amount of fall, and hence of available power, is between the mouths of the Watonwan and Le Sueur rivers, where it averages 10 feet per mile. The bed and banks are largely lime rock, and high bluffs border the river. Below the Le Sueur there is no fall of any importance. Above the Watonwan are a few unimproved powers, but most of the available power is in use. The banks of clay and gravel are there high enough to prevent flowage from the ponds.

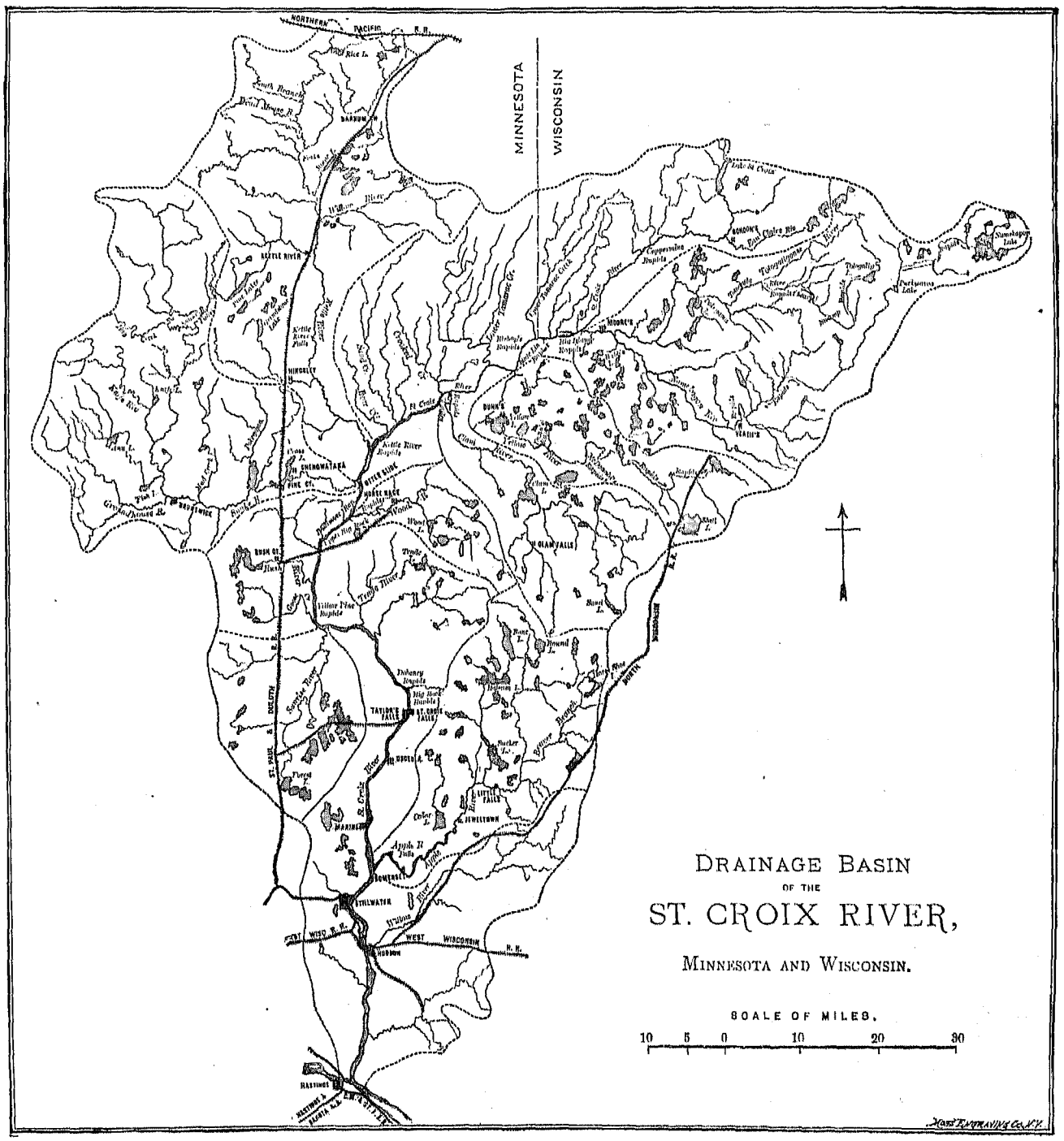
There is only one improved power between the Watonwan and the Le Sueur rivers, although on this portion of the stream a head of 10 feet will furnish power for six runs of stones practically through the year, with only occasionally times when the power would be less. Above the Watonwan about three runs of stones could be worked profitably with a head of 10 feet. There is only one improved power below the mouth of the Watonwan, that is at Rapidan, where the Rapidan Mill Company has a flouring-mill with four runs of stones under a head of 10 feet. The next mill is about 20 miles above the mouth and has three runs of stones under a head of 8 feet. Two miles above, at Vernon Centre, is an old mill with a head of 6 feet and two small runs of stones. About 5 miles above Vernon Centre are the Champion mills with three runs of stones under a head of 6 feet. Five miles above is a mill with three runs of stones under a head of 7 feet. About the same distance above the last mill is one opposite Winnebago City with a head of 10 feet and three runs of stones. Above Winnebago City is a mill with two runs under a head of 6 feet, then a small mill of only one run, and, finally, 1 mile below Winnebago City, a mill of two runs under a head of 6 feet.

Le Sueur river.—There is not so much fall in this stream as in the Blue Earth. The Maple and the Cobb rivers, its large tributaries, enter within 4 or 5 miles of the mouth. On the lower part of the river six runs of stones can be profitably worked under a head of 10 feet throughout the year. In the latter part of 1880 the Red Jacket mills were burned down, which were situated near the mouth of the river. They had four runs of stones under a head of 9 feet, but could have obtained a head of 11 feet.

There is an old saw-mill, with a head of 8 feet, a few miles above the Cobb river, and that is the only mill upon the stream, though there are some undeveloped powers.

Of the two chief tributaries of the Le Sueur the Cobb river is small and unsteady and has no developed powers. The Maple, likewise, is limited in power. The only mills of much importance are the Maple River mills, which have three runs of stones and two wheels under a head of 14 feet, rated at about 60 horse-power. Steam is used during low water. At Mapleton, near the head of the river, is a mill which takes the water from an artesian well in addition to the flow of the river itself.

Watonwan river.—This river is not so large as the Le Sueur, but stands next to the Blue Earth in importance as regards improved power. As regards uniformity of flow it has much the same general characteristics as the Blue Earth, and there are times in which it is impossible to run the mills; but with a head of 10 feet it can be depended upon to give power for three runs of stones nearly all the year. The bed and banks are of clay and gravel, and the banks are high enough to restrict the ponds to the river-channel.


MINNESOTA
WISCONSIN
NORTHERN PACIFIC R.R.
DULUTH
ST. PAUL
STILLWATER
HASTINGS
WEST WISCONSIN R.R.
DRAINAGE BASIN
OF THE
ST. CROIX RIVER,
MINNESOTA AND WISCONSIN.
SCALE OF MILES.
10 5 0 10 20 30

There are five mills upon the Watonwan. The first is 3 or 4 miles from the mouth, a three run mill with a head of 8 feet. At Garden City, about 5 miles above the mouth of the river, are two mills. The lower one has three runs of stones under a head of 7 feet, and the upper one three runs under a head of 8 feet.

At Watonwan, about 3 miles above, is a mill with one run of stones under a head of 7 feet, and the last mill on the river is one at Medalia, some 10 miles above Watonwan. It has two runs under a head of 11 feet. There are a number of unimproved powers.

Two miles above Garden City is a site where, by constructing a low dam and running a race across a neck of land, a head of 10 feet can be obtained. There are, apparently, many places where it would be practicable to throw a dam across the stream and obtain a moderate head of water.

TRIBUTARIES OF THE MISSISSIPPI IN WISCONSIN.

A glance at the map shows that all the western and most of the central portion of the state of Wisconsin drain into the Mississippi, and that the prominent features of the system of drainage are three large streams—the Saint Croix (partly belonging to Minnesota), the Chippewa, and the Wisconsin. These are the largest three rivers of the state, and on account of their geographical relations, and the general similarity in the topography of their basins, and in their hydrology, they will be discussed in the order given, previously to considering the smaller streams which enter the Mississippi from the west below the Minnesota river.

They are similar in rising on the elevated ridge which separates the drainage of lake Superior from the waters running to the gulf of Mexico. They all flow in the same general direction, a little west of south, across the Archæan base of the continent, into the region of the sedimentary rocks. On this account, largely, the upper waters are characterized by rapids, while the slope of their lower sections is more uniform. The sources are in wild regions of lakes, tamarack and cedar swamps, and sand ridges. The upper portions of their basins are covered with timber, largely pine, which gradually disappears in passing south, until finally the hardwood also is limited to groves and the lower portions of their basins assume in part the characteristics of a prairie region.

The great industry on each of these streams has been lumbering, and their basins have yielded much wealth to the state.

Because of the position of the Black River basin, wedged in between the Chippewa and the Wisconsin, that stream has been included in its order of occurrence.

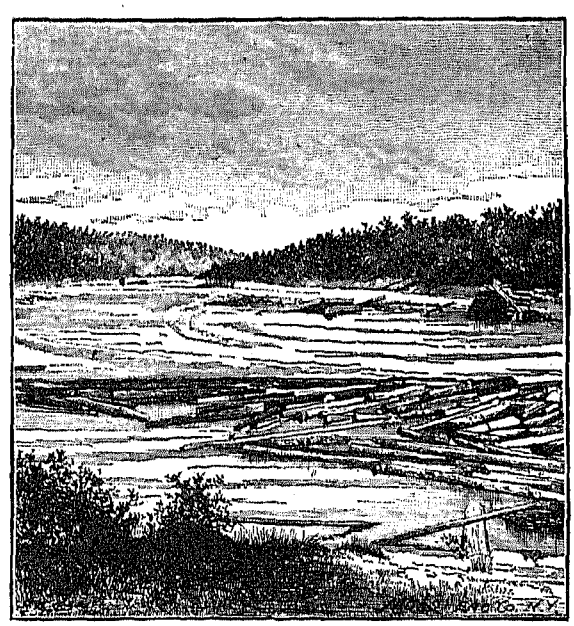
SAINT CROIX RIVER.

This stream ranks with the Chippewa and the Wisconsin as being among the prominent tributaries at the headwaters of the Mississippi. The mouth is on the east side of the Mississippi, 557 miles from its source, and 20 miles below the city of Saint Paul. The source is in what is known as Upper lake Saint Croix, near the divide which separates the drainage of lake Superior from that of the Mississippi. The river is 168 miles long, and in the lower three-quarters of its course forms the boundary between Minnesota and Wisconsin. The drainage area is 7,576 square miles, the larger part lying within Wisconsin.

The two important tributaries in Minnesota are the Kettle river and the Snake river, draining about 1,000 square miles each. In Wisconsin there is one large tributary, the Namecagon, draining 1,025 square miles, and several others with basins from 200 to 400 square miles in extent.

The Saint Croix flows almost exclusively in the lumbering region of the northwest. Being a wooded region, not as inviting to settlers as the open prairie found along the Minnesota river, the country is comparatively a wilderness; it is only in the southern portion of the basin that the land is much cultivated.

The Saint Paul and Duluth railroad runs north through the basin in Minnesota, and the Northern Wisconsin is partly constructed from near the mouth of the river northeast toward Bayfield, on the shore of lake Superior; but these roads have done little as yet toward the settling of the country through which they run.



The Saint Croix river, from above Taylor's falls.

Lumbering has been the one business of the entire region, but, at the present rate, the cutting of pine will cease to be profitable in the course of from fifteen to twenty-five years. There are several towns upon the lower part of the river, as Stillwater, Hastings, and Taylor's Falls, which owe their prosperity in the past to the lumber trade and

which are already too well established to be ruined by its decline. Taylor's Falls is one of the oldest towns in Minnesota, having been settled in 1837; and Stillwater, 25 or 30 miles farther down the river, was settled in 1843.

Character of the soil and timber.—Although so largely woodland there is a wide difference between different sections of the Saint Croix basin; and this is due to the varying nature of the soil. This is entirely drift, but differing in character. A large part of the basin is till, consisting largely of clay soil, and supporting a growth of hardwood, interspersed with pine; but passing northeast through the basin, bounded on the west by the river itself is a tract of land 10 or 15 miles wide, extending almost to the shore of lake Superior, and consisting of a light, sandy soil. On this is a worthless growth of pitchy pine, scrub-oak, and poplar. Half way up the river, in Wisconsin, the timber is chiefly hardwood, with perhaps one acre of pine to ten acres of other kinds of timber. Above the Wood river "the barrens" occupy all the lower portions of the tributaries on the east side of the river, but farther back, upon the headwaters of these tributaries and their branches, is found valuable pine timber, interspersed with hardwood and inferior qualities of soft wood. On the west side of the Saint Croix there is little pine timber until the region of the Snake and Kettle rivers is reached. On these streams and their tributaries are valuable pine lands.

In the region east of the Kettle river and north of the Saint Croix there are indications that a great fire occurred years ago. It is said that by digging up the soil coals can be found. No valuable pine is found, but the land is covered by a second growth of small pine, cedar, spruce, poplar, etc.

Flow of the streams.—The wooded character of the basin, the many lakes, and tamarack and cedar swamps, and the light sandy nature of so much of the soil, are all favorable to a steady distribution of the flow of the streams. The result is that the Saint Croix ranks with the Chippewa and the Wisconsin as being one of the three steadiest tributaries of the Mississippi, omitting some minor branches at the extreme headwaters of the Mississippi. Its ordinary low flow is about 0.37 cubic foot per second per square mile.

The sandy region, with the impervious substratum at the extreme upper waters of the river, especially, is very marked in its action. There are scarcely any streams in it, and this is because the water immediately sinks below the surface, reappearing in steady flowing springs along the rivers. Thus, the lake which gives rise to the Saint Croix river, a sheet of water some 4 miles long by one-half mile wide, is fed by many springs coming out of its banks, besides numbers bubbling through its bed.

Because the water gradually seeks the streams through the ground, they are very uniform in their flow; also, as the loss from evaporation is small under these circumstances, the total flow for the year bears a high ratio to the rainfall.

In the accompanying tables the average flow per square mile for the entire basin is used in calculation for the different sections. This, of course, can give only approximate results, as must be evident from the preceding remarks regarding the topography, but time does not permit a more complete application of the ratios of flow for different kinds of country deduced in treating of the entire Mississippi basin. It is not probable that the results obtained differ very greatly from the true amounts.

Table of fall, flow, etc., of the Saint Croix river.

Station.	Distance from preceding station.	Distance from the source.	Intermediate fall.	Total fall from the source.	Drainage area above station.	Flow per second past station.		Theoretical horse-power under 10 feet head.	
						Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Miles.*	*Feet.*	*Feet.*	*Sq. miles.*	*Cubic feet.*	*Cubic feet.*	*H. P.*	*H. P.*
Source				0					
Above mouth of Eau Claire river	6½	6½	2	2	117	47	96	53	109
Mouth of Eau Claire river	0	6½	2	2	224	83	183	94	208
Copper Mine rapids					366	135	299	153	339
Mouth of Namecagon river		38	100	102	1,451	537	1,187	609	1,347
Mouth of Yellow river	12	50	20	122	2,084	771	1,705	875	1,934
Above mouth of Clam river	12	62	22	144	2,428	898	1,986	1,019	2,253
Mouth of Clam river	0	62	0	144	2,844	1,052	2,326	1,193	2,639
Above mouth of Kettle river	11½	73½	50	194	3,046	1,127	2,492	1,279	2,827
Mouth of Kettle river	0	73½	0	194	4,139	1,531	3,386	1,738	3,841
Mouth of Snake river	4½	78	26	230	5,097	1,886	4,169	2,140	4,730
Mouth of Wood river	6	84			5,281	1,954	4,320	2,217	4,901
Mouth of Sunrise river	16	100			5,857	2,167	4,791	2,458	5,435
Saint Croix rapids	20	120	111	341	6,202	2,295	5,073	2,604	5,755
Mouth of Apple river	18	138			6,951	2,572	5,686	2,919	6,451
Mouth of Willow river	13	151			7,301	2,700	5,972	3,063	6,775
Mouth of Saint Croix river	17	168			7,576	2,800	6,197	3,176	7,030

Table of tributaries of the Saint Croix river.

River.	Length (map measurement).	Drainage area.	Discharge per second.		Theoretical power under 10 feet head.	
			Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Sq. mls.*	*Cu. feet.*	*Cu. feet.*	*H. P.*	*H. P.*
Saint Croix above Eau Claire river ..	7	117	47	96	53	109
Eau Claire river	25	107	40	88	45	101
Namecagon river	85	1,025	379	838	430	951
Yellow river	50	310	115	254	130	287
Clam river	50	410	154	340	175	387
Kettle river	70	1,003	404	894	458	1,014
Snake river	78	937	347	766	394	869
Wood river	30	108	62	137	70	155
Sunrise river	30	202	108	239	122	271
Apple river	55	427	158	349	179	396
Willow river	35	240	91	201	103	228

Reservoir system.—In connection with the "reservoir system" for improving the navigation of the upper Mississippi, 14 sites have been surveyed and found practicable for reservoirs within the Saint Croix basin. The estimated cost of their construction is about $430,000, and it is estimated that by means of them an addition of 2,600 cubic feet per second can be made to the low flow of the river during 120 days of low stage. This would nearly double the ordinary low-water discharge of 2,800 cubic feet per second, and would have nearly as great an effect upon the water-powers as it has been shown would take place on the upper Mississippi above the Minnesota river by the introduction of the "reservoir system" in that region.

Water-powers of the basin.—According to the records of the United States engineers, the lake which forms the source of the Saint Croix is at an elevation of 1,010 feet above the sea. This makes the total fall of the river to its mouth 344 feet, and the average slope 2.05 feet per mile. The slopes of the tributaries vary from 3 to 6 feet or more per mile. On account of these very considerable slopes, there is much water-power in the Saint Croix basin which will be utilized when farms and population bring into that region a demand for manufacturing.

The water-power sites are not limited to the subordinate streams. On the Saint Croix itself are numerous rapids, and in the lower portion of the river, below where the large branches add their flow, are the Saint Croix rapids, a fine site, where a fall of between 30 and 40 feet awaits improvement.

There are a few powers in use upon the lower tributaries, especially on the Apple river, but none upon the main river. There are, however, between 60 and 70 dams within the basin, built for the purpose of flushing logs into the main stream from the smaller ones. In the driving season the gates are opened and the logs float down upon the full current. The frequent occurrence of these dams indicates the undeveloped powers of the rivers.

The isolation of the upper portion of the river rendered all personal examination there impracticable, and the following brief description was obtained mainly from old lumbermen familiar with the entire country.

THE MAIN RIVER.

For the first 23 miles, up to Stillwater, the river averages about half a mile wide and the current is slight. The upper portion of this expansion is called lake Saint Croix. At Stillwater the bluffs rise steep on both sides to the height of 150 or 200 feet. About three-quarters of a mile above the town the lake ends and the river assumes its normal width. The head of navigation is at Taylor's falls, at the foot of Saint Croix rapids, about 50 miles above the mouth. The river mostly flows in a valley bounded by bluffs, with a flat on one side or the other. As a general thing it keeps close to the left or east bluff, and the right bluff is from 1,000 to 3,000 feet distant. The rapids in the river are generally over rock, while gravel, clay, and sand form the bed in the still stretches of its course.

From the outlet of upper lake Saint Croix down to the mouth of the Eau Claire, a distance of 6.5 miles, there is only a fall of 2 feet in the river. From thence to what is known as the Big dam (logging dam), a distance of 8.5 miles, there is about 7 feet of fall. In the next 23 miles, to the mouth of the Namecagon river, there is a descent of 93 feet, or 4 feet per mile, and many rapids occur, among which Copper Mine rapids may be mentioned.

Above the mouth of the Namecagon the ordinary low-flow power under a head of 10 feet is at least 150 theoretical horse-power.

The Namecagon is the second in extent of drainage area of all the tributaries, and when it enters the main river it increases the power of the latter, under a head of 10 feet, to 600 theoretical horse-power, with the ordinary low flow.

In the 12 miles from the mouth of the Namecagon to the mouth of the Yellow river, the total fall is 20 feet. Names have been given to three rapids within that distance, namely, Big Island rapids, State Line rapids, and Bishop's rapids. Each of the first two is described as affording fine opportunities for developing water-powers. At Big Island rapids the river runs close to the bluffs on the left bank, but a dam would need to extend some distance across the flat on the right.

From the mouth of Yellow river down to the head of Kettle rapids, a distance of 21 miles, the average slope is 1.8 foot per mile, and the river is good for logging, there being no rapids of special importance. It is very probable, however, that available water-power sites can be found in that section.

Kettle River rapids.—The Kettle River rapids are, next to the Saint Croix rapids, the most prominent on the river. They start 2.5 miles above the mouth of Kettle river, which enters from the west, and end 1.5 mile below it. In this length of 4 miles the total fall is 49 feet, of which 34 feet is above the mouth of Kettle river. Two islands from 1 mile to 2 miles long divide the river into two channels. The bed of the river is solid rock, and it is practicable to build several dams. As to the best method of improving the power it is impossible to speak without examination of the locality. Above the mouth of the Kettle river a head of 10 feet would afford 1,280 theoretical horse-power, with the ordinary low flow; and below the entrance of the Kettle river 1,737 theoretical horse-power, under the same conditions of flow, according to the estimates previously described.

Above the mouth of the Snake river, which enters 4.5 miles below the Kettle river, there is 11 feet of fall from the foot of the rapids.

Below the river, down to Saint Croix rapids, there are the following rapids, which have received names: The Otter Slide, just below the mouth of the Snake, the ordinary low-water power of which, under a head of 10 feet, is 2,140 theoretical horse-power; the Horse Race, 1 mile below; the Baltimore rapids, a mile below the mouth of the Wood river, the ordinary low-water power of which, under a head of 10 feet, is 2,220 theoretical horse-power; the Upper Big Rock rapids, about 1 mile below them; and the Yellow Pine rapids, about 3 miles above the mouth of Sunrise river. The amount of fall at each of these rapids cannot be determined from the data at hand.

Baltimore rapids were described as offering advantages for development. Yellow Pine rapids are 2 miles long and not very heavy. The total fall from the mouth of Snake river to Saint Croix rapids is 111 feet, and the average slope is 2.64 feet per mile. This must afford opportunities to develop power with what will be a reasonable expense at some time in the future. At the Horse Race the river runs close to the eastern bluff, and it would be necessary to extend a dam some distance across the flat on the west bank if a high head were utilized. Very probably the same would be necessary at most sites along the river.

Saint Croix rapids.—The Saint Croix rapids offer fine opportunities for water-power, and were used at one time, but now the river flows unemployed. There is a total descent of 55 feet in the 6 miles, which may be included under the name of Saint Croix rapids. Several local names are indefinitely applied at different points. At the foot are Taylor's falls, about three-quarters of a mile above are Saint Croix falls, then Tuttle's falls, etc. Strictly speaking there are no falls in the entire distance, only a more rapid decline in the bed at certain places.

The village of Taylor's Falls is situated in Minnesota, at the foot of the rapids, about 50 miles above the mouth of the river, at the head of navigation. Saint Croix Falls, a village of Wisconsin, is situated upon the slope overlooking the river from that side, nearly opposite Taylor's Falls.

Directly below the rapids the river enters the Dalles of the Saint Croix, where for half a mile or more it passes between vertical cliffs of trap-rock with sharp edges and bold angles. Just above the entrance into the Dalles the waterway is so contracted that when the river is high the water forms a fall of nearly 5 feet before it can overcome the resistance, but there is no very rapid descent there in low water. It is to this portion of the river that the name of Taylor's falls is given. Above the Dalles the rock continues in the bed, and to a certain extent in the banks of the river, but the valley spreads out considerably.

On the Minnesota side the bank rises steep from the river for 30 or 40 feet at the lower part of the rapids; back from this for several hundred feet is a nearly level plain, swampy in places, and bounding this are the bluffs, rising fully 100 feet higher. At the foot of the rapids the plain narrows and is lost in the Dalles. On the Wisconsin side, in the vicinity of Saint Croix falls, the slope is rather more uniform up to the general level of the country. At the entrance into the Dalles the river is scarcely more than 100 feet wide. At Saint Croix falls, three-quarters of a mile above Taylor's falls, it is between 200 and 300 feet wide, the average width of the river in this part of its course.

The portion of the rapids known as Saint Croix falls presents the most favorable site for improvement of the power, and here a dam was once built and saw-mills were run. The bed is solid rock, and the banks rise abruptly from the river on both sides. On the Minnesota side a large, high mass of trap-rock stands out in the channel, and forms a natural abutment for a dam; on the Wisconsin side the rock bank rises to a considerable height above the water in a rib, and back of it is a depression which leads to the slope upon which the village of Saint Croix Falls is situated. The improvement, long since gone to ruin, consisted of a dam built across the river at the point described, and a race blasted through the rock in the line of the depression on the Wisconsin side, and then carried down the slope along the river front, giving a head of 25 or 30 feet. The dam was a very extensive structure, raising the water to a height of 25 feet when in good condition. It was 300 feet long, 24 feet wide at the top, and

only 60 feet wide at the base. Wedge-shaped log cribs were built in the stream with spaces between them; similar cribs were built up-stream and floated down into these spaces, until finally only the central space was left open, through which the river flowed. The two cribs on each side of this space were built with shoulders projecting against the current. Finally a crib built accurately, with corresponding shoulders to fit into this space, was floated down into place, and the channel was closed. The crib-work was planked over. The dam was not cared for, the planking and crib-work were partly destroyed, a portion being cut away to make a passage for logs, and finally the whole dam was washed away.

The same natural facilities exist for developing this water-power as formerly, but the interests upon the two sides of the river are owned by different persons, and there will be some difficulty in coming to an agreement. If the dam were built so as to give a head of about 40 feet, which is practicable, a race could be carried down the plain on the Minnesota side for a long distance as readily as on the Wisconsin shore. The pond would probably back water 4 or 5 miles, and would not overflow much land.

With the ordinary low flow the power under a head of 30 feet is 7,811 theoretical horse-power, and under a head of 40 feet 10,415 theoretical horse-power. With the yearly average flow it is 17,266 theoretical horse-power under a head of 30 feet, and 23,021 theoretical horse-power under 40 feet.

There is about 5 feet of fall in the river from the site of the dam to Taylor's falls. Here is an excellent site for the construction of a dam, which would scarcely be more than 100 feet long, but the vertical cliffs come close to the river just below, leaving only room for a small steamboat landing, without space to erect extensive manufactories.

TRIBUTARIES OF THE SAINT CROIX RIVER.

As they are mainly in the almost uninhabited woods, very little information can be obtained about the water-powers of the tributaries of the Saint Croix. Nearly all of them are known to have considerable descent, and because of the wooded, swampy character of the land, as well as the sandy nature of much of the soil, they have in the main a very steady flow throughout the year.

As has been previously mentioned, the general average for the entire basin has been assumed for each tributary, and hence in making the calculations 0 37 foot per second per square mile has been taken as the ordinary low flow. That it may be over 0.40 of a cubic foot per second per mile for some of the streams at the headwaters is probable, and then again it may fall below the average in the case of several streams tributary to the lower portion of the river.

When the country is settled so as to create a demand for water-power, the woods will be largely cleared away, the swamps drained, etc., and this will tend to diminish the steadiness of flow, so valuable a consideration in questions of this kind.

The Namecagon, Kettle, and Snake rivers present the largest powers, and as the Namecagon drains almost entirely from the sandy region called "the barrens", it is probably one of the most steady rivers of the entire system. The Kettle and Snake rivers drain extensive regions of tamarack swamps and woods, which cannot fail to have a great influence upon the flow.

NAMECAGON RIVER.

The United States engineers' reports state that the average slope of the Namecagon is about 5 feet per mile, and as the length is 75 or 100 miles, the total descent is, according to this estimate, not far from 500 feet. From the source down to Vezies, which is about 25 miles above the mouth, "the river is generally narrow and rapid, stretches of rapids over native trap-rock being frequent. There are also several vertical falls of from 2 to 4 feet." "From Vezies to the mouth the river is from 100 to 200 feet wide, and there are several sharp pitches and rapids, the principal of which are Little and Big Ball rapids, and Dupee flats."

The descent appears to be rather uniformly distributed, considering the entire river. There is a descent of 40 feet in the first 12 miles above the mouth of the Totogatic, and in the first 6 or 10 miles above Vezies there is at least 30 feet of fall. The source of the Namecagon river is a lake some 10 square miles or more in extent, having the same name. The lumbermen have a dam affording a head of about 7 feet just below the outlet of the lake, which floods the lake and stores sufficient water to "drive" for about three weeks. There is also a logging dam below Little Pequayon (*a*), and one called the Hanscomb dam about 2 miles above the Chippenazy creek.

The Totogatic is the largest tributary to the Namecagon, and lying to the north of the main stream drains over one-third of its entire basin. It enters the Namecagon about 5 miles from its mouth. The course is very winding, and in it there is considerable inequality of slope. There are three dams upon the river, the lowest some 12 or 15 miles below the source, and in this distance there are some slight rapids. From the lower dam down to the mouth of the Totogatic Ouse (Little Totogatic), a distance of 10 miles, there are heavy rapids. In this section are the Upper and the Lower falls, 6 miles apart, with rapids between. There is a vertical pitch of 10 feet over ledges of trap-rock at the Upper falls and at least 8 feet at the Lower falls. Below these is the Horse Race. The United

a Pequayon is the Chippewa for "dead-water."

States engineers' reports state that in this 10-mile section the river is entirely unnavigable for boats of any kind. Below the mouth of the Totogatic Ouse the river is good for logging and not so rapid; there are rapids however, especially in the lower part of the distance. In the last 10 miles of the river the fall is 40 feet.

The other tributaries of the Namecagon are all small, but have a rapid descent. Thus McKenzie's creek, which drains three lakes, has a fall of 33 feet in the last 2.5 miles, and the Chippenazy creek is crowded with logging dams, indicating a rapid fall to the main river.

KETTLE RIVER.

The Kettle river is described by the United States engineers as having "an average fall of 6 or 8 feet per mile over sharp pitches and long stretches of rapids. The banks are high and precipitous and the valley is narrow". For 7 miles above the mouth there are rapids, and then about 10 miles of slack-water. Above that, for some 14 miles, there are alternately rapids and quiet water. Then there is a long stretch of rapid water, and near its upper portion are Kettle River falls, with a vertical pitch of 12 feet. From these rapids up to the mouth of the Moosehorn river, there is quiet water nearly all the way, and above that are more or less rapids, but the stream becomes small and of little importance so far up. The Saint Paul and Duluth railroad crosses the river at a settlement called Kettle River, and the Northern Pacific railroad crosses the headwaters.

SNAKE RIVER.

The Snake river is not as large as the Kettle river, but has a rapid descent in places. From the mouth up to the Chengwatona dam, a distance of about 14 miles, the average slope is 11 feet per mile, and there are "almost continuous rapids over trap-rock ledges and bowlders".

Just above Chengwatona dam is Cross lake, and a few miles above, Pokegama lake, both flooded by the dam, which is used for driving logs over the rapids below into the Saint Croix. It is owned by persons in Saint Paul, who charge a toll of 10 cents per 1,000 feet passing the gates. The head is from 8 to 9 feet, and at a cost estimated to be $15,000 might be increased to 13 feet. This would flood up the river to Brunswick, a distance of 24 miles.

Above Brunswick the river is rather sluggish for 20 or 30 miles, but above that there are many rapids, including Snake River falls with a vertical pitch of 8 feet. The rapids in the river are over solid rock or bowlders, and the banks are composed mainly of yellow clay or of sand and gravel. The side streams are mostly narrow and rapid. The Groundhouse, entering at Brunswick, is the principal tributary. Upon it is a grist- and saw-mill, using about 20 horse-power under a head of 6 feet.

YELLOW RIVER.

The Yellow river is a very steady stream, draining 310 square miles of the barrens. Several lakes, notably Yellow lake, near the mouth, tend to regulate the flow. The stage varies through the year only from 1.5 foot to 3.5 feet, according to the locality. There are a number of rapids on the stream and many practicable water-power sites are to be found. From Yellow lake the rapids are described as almost continuous down to the mouth of the river, a distance of 10 or 15 miles. There are four logging-dams upon the river, one flooding Yellow lake.

CLAM RIVER.

The Clam river, draining 416 square miles, is formed by two branches, the North fork and the South fork, which unite at the head of Clam lake. At the foot of this lake is a dam which stores water sufficient to drive logs to the mouth of the river. There are rapids below the junction, and many opportunities for developing water-powers. Above the junction, on both branches, there are rapids and dams used for logging. On the South fork are the Clam falls, where there is a head of 15 feet, of which 6 or 8 feet has been used by a saw-mill.

APPLE RIVER.

The Apple river flows through a comparatively settled region and has several improved water-powers. A large amount of lumber is still brought down from the upper waters, and there are a number of dams used for driving. The area drained by the Apple river is 427 square miles. At the headwaters are ten lakes, one of them 6 miles long and from one-half to three-quarters of a mile wide. There are a large number of water-power sites available. According to the statement of a person familiar with the river the first improved power is at Somerset, 5 or 6 miles above the mouth of the river. There is at that point a flouring-mill and saw-mill with a head of 10 feet. At Jewelton, some 15 or 20 miles up the river from the mouth, there are two flouring-mills and a saw-mill under a head of 10 or 12 feet, and a few miles above are a flouring- and saw-mill with about the same head of water. These are the only mills upon the river. Between the two last mentioned powers is a fine unimproved power, but the largest is at Apple River falls below Somerset. These falls have been a source of considerable expense to the lumbermen in the effort to improve them for driving. By cutting a canal across a bend in the river a head of about 35 feet could be obtained.


DRAINAGE BASIN
OF THE
CHIPPEWA RIVER,
WISCONSIN.
SCALE OF MILES.
10 5 0 10 20 30

SMALLER TRIBUTARIES.

The Sunrise river, Willow river, Wood river, etc., have mills upon them, but it is evident from their number that the resources of these streams for small powers are not exhausted. The only power used on the Sunrise is at Sunrise City, a few miles above the mouth. There are two flouring-mills under heads of 9 and 12 feet, respectively, and a saw-mill under a head of 12 feet.

According to the census returns, there are two small flouring-mills and two saw-mills on the Wood river, and one flouring-mill on the Trade river, a little stream which enters below.

The Willow river, which flows into the Saint Croix near its mouth, is the most extensively improved of all the streams of the basin. Upon it are five flouring-mills and one saw-mill. One of the flouring-mills uses 195 horse-power under a head of 16 feet, and another 150 horse-power under a head of 12 feet.

CHIPPEWA RIVER.

The Chippewa river extends southwest across Wisconsin, from the border of Michigan to the Mississippi at the foot of lake Pepin. The river has its utmost sources on the divide separating the drainage of the great lakes from that of the gulf of Mexico, and after flowing 165 miles enters the east side of the Mississippi, 611 miles below its source. The 9,573 square miles of territory drained by the Chippewa is situated chiefly in the wild, unsettled region of northern Wisconsin, and resembles the Saint Croix basin in being a great lumbering region. Millions of feet of pine are cut every year and sent down the stream, either to be manufactured by mills situated on the river, or else rafted to points on the Mississippi below the mouth of the Chippewa, and there made into lumber.

As with other lumbering rivers, the pine of the Chippewa region is fast being cut away, and the camps are now located far up toward the headwaters of the stream. The settled portion of the basin proper is the southwestern end, where the wooded region gives place to the prairie which extends west to the Rocky mountains. The only railroads are the Chicago, Saint Paul and Minneapolis, crossing the river at Eau Claire, about 50 miles from the mouth, and the Wisconsin Central, which has two branches, one passing northward across the sources of the river to Ashland on lake Superior, the other passing west to the Chippewa river at Chippewa Falls, about 10 miles above Eau Claire, where it connects with the first-mentioned road. Eau Claire and Chippewa Falls are the most prominent towns of that region, and have owed their prosperity in the past to the lumber trade.

The settled portion of the basin does not extend very far above Chippewa Falls. East and north the country is covered with timber of various kinds, including pine. The soil is the drift, consisting of clay, sand, and gravel. In some places arenaceous soil predominates. There is no marked distinction, such as is found in the sandy "barrens" of the Saint Croix region. The fact of the growth of pine indicates a lighter soil than the stiff clay of the prairie, and it is probable that sand and clay occur irregularly associated throughout the basin.

The wooded region consists very largely of tamarack and cedar swamps, and in them are found large amounts of peat. Interspersed throughout this region are many lakes, upon which the growth of vegetation has not yet made sufficient advances to convert them into swamps. The country is level or rolling. Toward the south the streams have cut deep into the drift, but northward, about the sources, they are small and have not yet worn their way much below the surface.

System of drainage.—The main line of drainage runs very nearly along the central line of the basin, but the name of the river is not given to this continuation of the principal stream. The stream divides 112 miles above the mouth; one branch, the prolongation of the line of drainage, rises in the extreme lakes on the border between Wisconsin and Michigan, and is called the Flambeau river; the other flows more directly from the north and receives the name of the Chippewa. The Flambeau drains 1,083 square miles, while the main stream above the junction drains only 1,777 square miles. About 56 miles above the Flambeau the Chippewa again divides into the West and East branches, the one flowing from the north, the other from the northeast, and draining, respectively, 480 and 278 square miles. The chief tributaries, in the order of their occurrence, are the West and East branches, the Courte Oreille, the Flambeau, the Jump, Yellow, Eau Claire, the Menomonee, and Eau Sale rivers. The Menomonee flows nearly south, and enters the main stream about 23 miles from its mouth. It drains 1,957 square miles, and on account of its peculiar position a large part of the drainage of the Chippewa river does not reach that stream until near its entrance into the Mississippi.

Fall of the streams.—At Chippewa crossing, where the Wisconsin Central railroad crosses the East branch, the water surface is 1,509 feet above sea-level, and as the mouth of the river is 660 feet above the sea there must be nearly 900 feet of total fall in the river, or about 4.5 feet per mile. From the junction of the two branches down to the mouth the total fall is 621 feet, and the average slope 3.76 feet per mile. This is a heavy fall, and causes many rapids in the course of the river. The tributaries likewise abound in rapids, but from the scarcity of elevations obtainable for them and the main stream I can only state the existence of a great deal of rapid water. These rapids give rise to a large amount of water-power which will be available when the country is settled and the wants of the population are to be met, but at present these powers are wasted, with the exception of one on the main river at Chippewa Falls, yet to be described, and a few improved sites on some of the lower tributaries. There is very little prospect of the rapids being improved at the upper waters of the basin for many a year to come.

Flow.—The comparatively uniform surface of the country, and its covering of timber, together with the lakes and swamps, tend to prevent the rapid escape of the water into the streams, and maintain the Chippewa, even in ordinary low flow, at an average of about 0.37 cubic foot per second per square mile. For the same reasons as in the case of the Saint Croix, the average for the entire basin has been used throughout in estimating the discharge of the tributaries, although more or less difference must exist between them in their ratios of flow. Streams like the Flambeau or the Courte Oreille, which drain many lakes and swamps, are in all probability more steady in their flow than the Thornapple and Yellow rivers, with their long, narrow basins, or the streams coming from the less wooded region in the southern end of the basin.

Table of distances, flow, etc., of the Chippewa.

Station.	Distance from preceding station (approximate).	Distance from the junction (approximate).	Drainage area above station.	FLOW PER SECOND PAST STATION.		THEORETICAL POWER UNDER 10 FEET HEAD.	
				Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Miles.*	*Sq. miles.*	*Cub. feet.*	*Cub. feet.*	*H. P.*	*H. P.*
Junction of the East and West branches	.....	0	757	280	692	318	785
Mouth of Courte Oreille river	14	14	988	366	916	415	1,039
Above mouth of Thornapple river	22	36	1,383	511	1,282	580	1,464
Above mouth of Flambeau river	17	53	1,777	667	1,647	757	1,869
Mouth of Flambeau river	0	53	3,761	1,392	3,486	1,579	3,955
Mouth of Jump river	7	60	4,666	1,704	4,270	1,933	4,844
Above mouth of Yellow river	30	90	4,926	1,823	4,566	1,068	5,780
Mouth of Yellow river	0	90	5,384	1,992	4,991	2,260	5,662
Above mouth of Eau Claire river	23	113	5,760	2,131	5,999	2,418	5,340
Mouth of Eau Claire river	0	113	6,659	2,464	6,152	2,795	6,979
Above mouth of Menomonee river	29	142	7,004	2,591	6,493	2,939	7,366
Mouth of Menomonee river	0	142	8,901	3,316	8,307	3,762	9,424
Mouth of Chippewa river	23	165	9,573	3,542	8,874	4,018	10,068

Table of tributaries of the Chippewa.

River.	Length (map measurement).	Drainage area.	DISCHARGE PER SECOND.		THEORETICAL POWER UNDER 10 FEET HEAD.	
			Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Sq. miles.*	*Cu. feet.*	*Cu. feet.*	*H. P.*	*H. P.*
West branch of the Chippewa	35	480	178	445	202	505
East branch of the Chippewa	60	278	103	258	117	293
Courte Oreille	20	176	65	163	74	184
Flambeau	155	1,983	734	1,828	837	2,085
Jump	65	721	267	678	303	769
Yellow	65	458	169	415	191	471
Eau Claire	65	899	333	893	378	945
Menomonee	95	1,957	724	1,814	821	2,058

Reservoir system and logging-dams.—Surveys have been made by the United States engineers for reservoir sites, and eleven have been selected upon the headwaters and one on the main stream at Paint creek, 4 miles below the mouth of Yellow river. Their total cost will be about $355,000, and it is estimated that by means of them 2,800 cubic feet per second can be added to the flow of the river for 90 days during the summer and fall. This would raise the ordinary low-water discharge of summer from about 3,500 to 6,300 cubic feet per second.

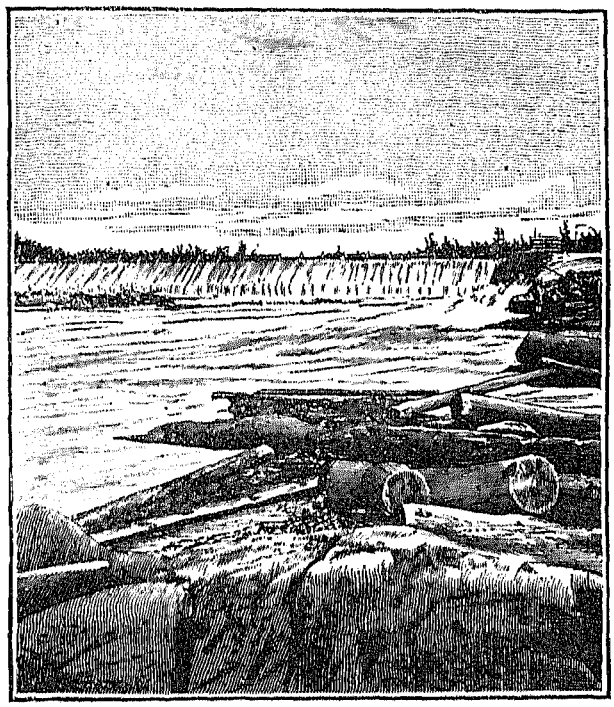
There are many dams upon the Chippewa and its branches for logging purposes, the same as in the case of the Saint Croix, but there are some upon the lower portion of the river much larger than any to be found on the latter stream. The three principal dams are the Dells dam, near Eau Claire, the Paint Creek dam, about 2 miles above Chippewa Falls, and the Little Falls dam, on the main stream some 4 miles below the mouth of the Jump river. There is also a dam at Chippewa Falls, giving a water-power at that place.

The Dells dam is the first one above the mouth of the river. The foundation is a fairly hard quality of sandstone. The construction is of square-timber cribs built up in crib-work. The dam is about 600 feet long and 19 feet high, 3 feet wide at the top, and with a base of about 8 feet. The slope on the upper side is about 3 to 1, and on the lower side 1 to 1. Both faces are planked over. The dam floods a large area, expanding the river to the dimensions of a lake, and when seen in the early summer of 1881 this was covered with logs as close as they could float for at least a mile in length and one-third or one-half a mile in width. The lower timbers of the crib-work are bolted to the rock by means of drift-bolts driven into holes which were previously filled with pine pins (the same method as was used in the dams at Minneapolis), and the different courses of the cribs are bolted to each other. At the foot of the lower face sleepers are bolted to the lower courses of timber and project down stream 20 feet. On them is an 8-inch covering of squared timbers to protect the bed from the plunge of the water. On the left bank are the sluice- and raft-slides, and on the right is a small flume leading to Half-Moon lake. Splash-boards are placed along the crest when necessary.

This dam was built by Mr. H. H. Douglass, agent of the Minneapolis Mill Company, and in this manner: During low water a coffer-dam was built out from the left bank and the sluice constructed, then another coffer-dam, and the dam built out toward the right bank; finally a coffer-dam was constructed from the right bank, and all the flow of the river turned through the newly-constructed sluice, and the dam built out from the right bank to meet the finished portion.

The Paint Creek dam is on the granite bed of the river, and, according to the United States engineers' report, is 526 feet long, with a crest 10.5 feet above low water. There is a rolling-dam 360 feet long, and in the center a rollway for logs about 100 feet long. There is also a lumber-slide 23 feet wide. The slope of the rear face is 1½ to 1, and of the front face 1 to 1.

The Little Falls dam is 625 feet long, with 267 feet width of sluice-way, and the height of the sluice-way above the flooring is 21 feet.



Point Creek dam, Chippewa river, Wisconsin.

The dams and the resulting reservoirs, controlled by the lumbermen, exert a very noticeable effect upon the flow of the river. The water is stored up till required, and then the gates are raised and the logs are sent down upon a flush of water. This causes an element of uncertainty in the flow, especially in the upper portion of the river, which would cause difficulty at times if manufactories were erected using the full flow; but nothing of that kind exists now, and the decline of the lumber interests will probably keep pace with the advance of manufacturing. If the existing reservoirs were managed solely with a view to steadying the flow of the river they would exert an important effect.

RAPIDS ON THE MAIN STREAM.

As before stated, little can be ascertained regarding the falls except from the reports of surveys by the United States engineers at the sources. Boats can ascend the river to Eau Claire, and there is no rapid in the stream below the Dells dam. "Below the mouth of the Eau Claire the maximum slope is 2.3 feet per mile, but only for a short distance, the mean slope being 1.64 foot per mile." In its natural state there were two rapids in the river between Eau Claire and Chippewa falls—one 1.25 mile above the Eau Claire, where the Dells dam is now situated, called the Lower Dalles, with 10.5 feet of fall in a little over 2 miles; the other about 4 miles below Chippewa falls, called the Upper Dalles, with 9 feet of fall in about 10,000 feet.

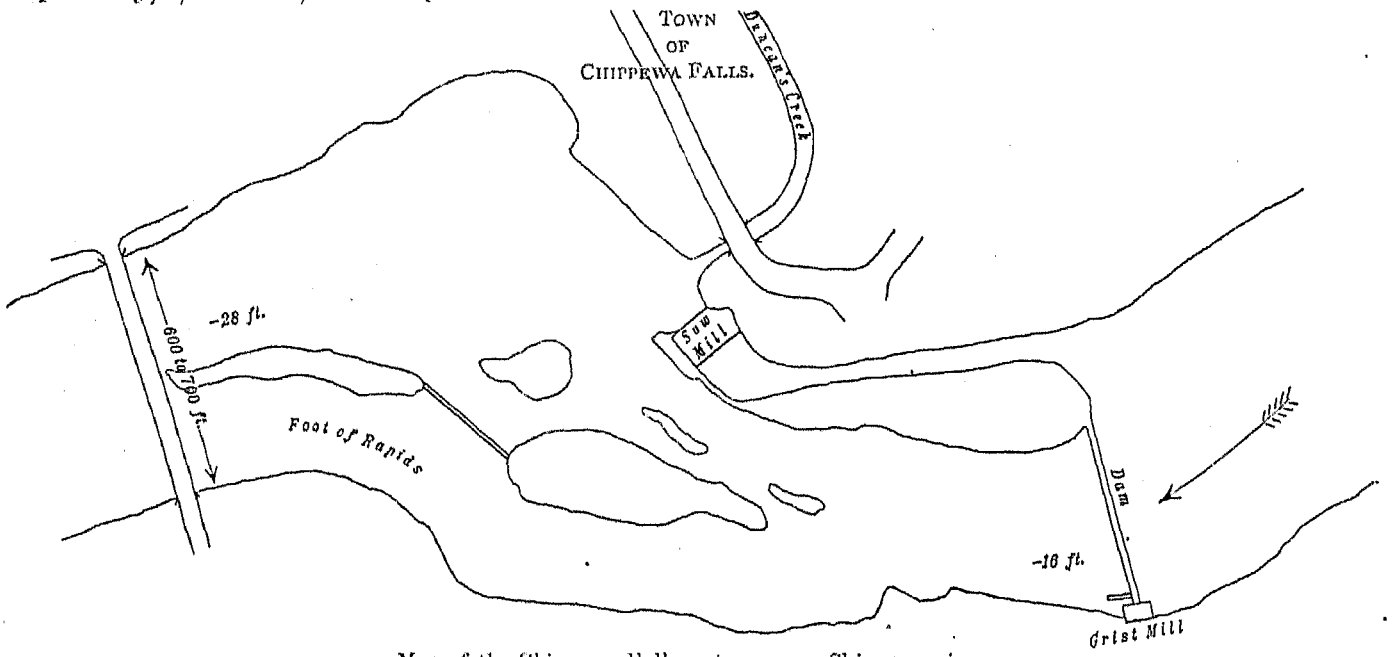
The next rapid is Chippewa falls, yet to be described. From Chippewa falls there are rapids or swift water distributed all along the river to the sources, and those familiar with the stream claim that the character of the bed and banks is such as to make it practicable to develop powers at a great many points. In the United States engineers' reports the statement is made that, from the mouth of Courte Oreille river down to the Big bend, the Chippewa has a swift current throughout the entire distance and no rapids of any consequence. The fact of the building of the Paint Creek and Little Falls dams indicates the existence of available power between Chippewa falls and the junction of the two branches of the river. On these branches the surveys of the United States engineers prove the presence of many rapids. Thus there is a fall of 43 feet in the last 2.75 miles of the East branch. At the head of these rapids is Little Chief lake, and from this lake up to Bear lake, a distance of about 15 miles, there is a rise in the river of 110 feet. The heaviest rapids in this distance are Cedar rapids, 54 feet in about 3 miles, and

Snaptail rapids, with a fall of 45 feet in about 1.5 mile. From Bear lake up to Chippewa crossing, where the Wisconsin Central railroad crosses the river, a distance of some 15 or 20 miles, the total rise is about 76 feet. The river at the crossing is near the divide which separates it from the Bad river, flowing into lake Superior, and is a small stream, from 25 to 40 feet wide. The West branch does not appear to be so rapid. From the junction to the mouth of Little Chief river the rise is only 7 feet in 5 or 6 miles. Above that is a succession of rapids and still reaches to Partridge Cross lake, the rise being 97 feet in 20 or 25 miles. Above the lake the river is sluggish to its source. This smaller slope of the West than of the East branch might be assumed from a knowledge of the general slope of the country, as the Lake Superior divide falls in passing from east to west. Assuming 0.37 cubic foot per second per square mile as the ordinary low flow, the theoretical power of the West branch under a head of 10 feet at the mouth is 200 horse-power, and of the East branch 120 horse-power. These are probably low estimates.

Power at the dams.—There are many powers immediately available at the dams which already exist, and were there any demand for them these powers would probably soon be used. The Dells dam is directly on the line of railroad; 16 feet of water is available at the dam, and there are rapids for several hundred feet below. With the ordinary low flow under a head of 16 feet the total power is not less than 3,800 theoretical horse-power, and with the average yearly flow it is over 8,500 theoretical horse-power.

At the Paint Creek dam the theoretical power under a head of 10 feet is 2,260 horse-power with the ordinary low flow, and with the average flow 5,660 horse-power.

At the Little Falls dam under a head of 10 feet the theoretical power with the two conditions of flow is, respectively, 1,930 and 4,840 horse-power.



Map of the Chippewa Falls water-power, Chippewa river.

CHIPPEWA FALLS—THE ONLY UTILIZED POWER.

It is said that there was at one time a mill at Chippewa City, a few miles above the mouth of Yellow river, but now the only power in use on the main river is at Chippewa falls. There the river, when in its natural state, rushed down over great masses of solid granite. Now a dam is built across the main channel from the left bank to a rocky island, then runs down that and across the smaller channel to the right bank. The town of Chippewa Falls is situated on the right or west bank of the river, extending down stream from the dam. Built along the face of the dam over the small channel is a large saw-mill, and on the eastern shore, at the extremity of the main dam, is a flouring-mill. These are the only establishments using the power.

There was formerly a bridge crossing the river just below the island, but it was carried away during the unusually high water of June, 1880. The total fall from above the dam down to the lower bridge is about 28 feet, of which 16 feet is at the dam, and when in a high stage, the river rushes down white with foam over the rocks below the dam. On the west side the shore takes a wide sweep inland, just below the saw-mill, forming a quiet bay, and there Duncan creek enters the river. The saw-mill is one of the largest in Wisconsin; there are three or four gang-saws and as many "rotaries", besides the necessary machinery for trimming the lumber and working the waste into laths and shingles. As many as 1,700 logs are sawed per day, giving about 450,000 feet (board measure) of lumber. At the foot of the building men are busy making rafts out of the lumber, which is floated out into the river, and so down-stream. The space in the west channel above the mill is used as a pocket in which the logs are held ready for use. There are in all seventeen wheels in use in the saw-mill, but the machinist does not

rank any of them as first-class wheels, some being the old-fashioned flutter-wheels; and the result is that much power is wasted. According to the census returns the total power used by the mill is 1,084 horse-power. The wheels work under a head of 14 feet, taking 7,440 "inches" of water. Considerable head of water is lost in the distance from the main pond down to the mill, as there is a strong current in the pocket, even when the water is falling over the crest of the dam near the mill, showing that it is not due to the wheels drawing off the water.

There is no difficulty experienced from backwater when Duncan creek is high, and ordinary high water on the river does not stop the wheels. The grist-mill at the end of the main dam uses 124 horse-power under a head of 12 feet. Hence there is only 1,208 horse-power in use where at least 3,600 horse-power is available with the ordinary low flow under a head of 16 feet. This bears out the statement made by the machinist of the saw-mill, that at a low stage of the river fully double the flow was available that was in use.

Utilized power at Chippewa falls.—The total fall from the quiet water above the dam down to the foot of the rapids is stated to be 28 feet. This would give, with the ordinary low flow, 6,300 theoretical horse-power, and with the average yearly flow, 15,800 theoretical horse-power. The power actually in use is only 1,208 horse-power, but there is great waste in the method of taking it. Even allowing an efficiency of only 50 per cent. for the wheels, there must be at least 3,800 theoretical horse-power unemployed at Chippewa falls during ordinary low water. This cannot be very well used directly at the dam. On account of Duncan's creek entering the river, the relation of the streets of the town, and the location of the saw-mills, there is not a very good opportunity for development on the right bank of the river, but on the left bank the situation appears much more favorable, so far as can be judged from a brief inspection. The true bank of the river is at an average distance of perhaps 100 feet from the water in ordinary stages, and extends down-stream nearly on the level of the top of the dam. Between this bank and the river is a mass of rock, while the bank itself is earth covering the solid rock, down which a canal could be extended, supplying mills.

Possibly in excavating the canal it would be found necessary to do some blasting in the rock. A short distance below the dam is the abutment of the bridge which was carried away in the freshet of 1880, and if this is rebuilt, some changes would be necessary in case of the construction of a canal. The railroad runs along the east bank of the river, and side-tracks could readily be carried down to manufactories along the canal.

TRIBUTARIES OF THE CHIPPEWA RIVER.

The Flambeau and the Menomonee are the largest two, the first draining 1,983 and the second 1,057 square miles. The next stream in extent of drainage area is the Eau Claire, with 899 square miles; then the Jump river, with 721 square miles; the Yellow river, with 458 square miles, etc. The West and East branches, draining respectively 480 and 278 square miles, have been already alluded to.

Like the two branches just mentioned, the tributaries have many rapids affording available sites, but there are few of them improved.

On the upper waters of the north fork of the Flambeau, from the crossing of the Wisconsin Central railroad up to Rest lake, a distance of about 75 miles, there is a rise of 126 feet, and 85 feet of this occurs, in the first 21 miles. There are several falls upon the Flambeau and its tributaries which have been considered of sufficient importance by the lumbermen to receive names.

The Jump river, as its name indicates, is a rapid stream, and so are the Yellow river and a number of smaller tributaries entering the Chippewa in that region. Their valleys are, however, mostly narrow, subject to rapid drainage, and the streams are not so steady in their flow as several of the other tributaries.

The Courte Oreille river drains an area of only 176 square miles, but its source is in a large lake of the same name, some 6 miles long by about 1 mile wide, and Grindstone lake, of nearly the same area, is tributary to it. These tend to regulate its flow. The river is sluggish in its first 3 miles, but in the remaining 12 or 15 miles to the Chippewa it is a succession of rapids and still water, including Courte Oreille falls. A reservoir site has been surveyed at the foot of the lake.

At Cadott, upon the Yellow river, some 10 or 12 miles from its mouth, are a flouring-mill using 20 horse-power under a head of 14 feet, a saw-mill, and a hub- and spoke-factory.

EAU CLAIRE RIVER.

The Menomonee and the Eau Claire rivers are controlled by the lumbermen. A lumber company, with the head office at Eau Claire, has a number of dams on the Eau Claire river, some of them close to each other, and this company has to a slight extent used the water-power under its control. The lowest dam is situated in the town of Eau Claire, and there the company has a flouring-mill on the left bank, using about 150 horse-power under a head of 8 feet. There are four runs of stones, and two sets of double rollers. On the right bank is a saw-mill using steam-power, but there is associated with it a small machine-shop run by water-power, and under the control of the company. The only other power used on the river is at one of the company's dams above, where it has a saw-mill

with a capacity for using 500 horse-power under a head of 12 feet. This is stated to be the capacity of the stream in low water. Assuming an ordinary low flow of 0.37 cubic foot per second per square mile, the theoretical horse-power at the mouth would be about 450 horse-power under a head of 12 feet.

MENOMONEE RIVER.

The Menomonee, called the Red Cedar on some of the maps, but now generally known by its old Indian name, Menomonee, has some twenty-five logging dams upon it. It rises in several lakes a few miles south of Lac Courte Oreille and the Namecagon river of the Saint Croix basin, and has already been described as draining nearly all the southwestern portion of the Chippewa basin.

The use of the great number of flushing-dams on the river renders its flow uncertain, and it is considered that when the lumber interests have declined the river will be much more desirable for water-power and will be more extensively used than at present. The river verges upon the prairie region, in its lowest part at least, and hence there is more prospect of the early development of its water-power than in the case of the Flambeau.

According to the census returns there are three flouring-mills on the Menomonee, one using 250 horse-power under a head of 11 feet, another 40 horse-power under a head of 10 feet, and the third 20 horse-power under a head of 16 feet. There are also three saw-mills using 1,000, 400, and 65 horse-power under heads of 11, 18, and 12 feet, respectively. There is also a foundery and machine-shop using 36 horse-power under a head of 11 feet. The large saw-mill and flouring-mill are situated at the town of Menomonee, which is 2 miles south of the railroad crossing, and some 15 or 20 miles above the mouth of the river.

There are many small streams in the southern part of the Chippewa basin which are already utilized by mills of various kinds, as, for example, the Aux Galle. Duncan's creek, which enters at Chippewa Falls, is 30 or 40 feet wide, and is fed by springs which make it very steady in flow, except when swollen by surface water. The machinist of the saw-mill at Chippewa Falls said that with a head of 12 feet it would furnish 35 horse-power at the lowest stage, and he would prefer it to a steam-engine of equal power. It is probable that there are many such spring brooks feeding the Chippewa which can furnish moderate powers of great constancy when required.

The census returns credit Duncan's creek with three flouring-mills of 132, 100, and 60 horse-power, under heads of 20, 10, and 12 feet, respectively; one saw-mill using 50 horse-power under a head of 12 feet; and two sash- and door-factories, each using 24 horse-power under a head of 9 and 10 feet, respectively.

BLACK RIVER.

The Black river is much smaller than those streams that we have just been considering, but from its position and general features may be properly classed with them. Its drainage basin of 2,272 square miles is long and narrow, wedged in between the Wisconsin on the east and the Chippewa on the west. In one place where the Eau Claire branch of the Chippewa, and the Poplar river, a stream of the Wisconsin basin, approach each other, the basin of the Black is scarcely more than 3 miles in width; it widens out above, however, to some 10 miles or more across. The general direction of the river is southwest, with a gradual bend from south to west, and it enters the Mississippi about 680 miles from its source, after a course of 128 miles. The mouth is about 10 miles above the city of La Crosse, Wisconsin.

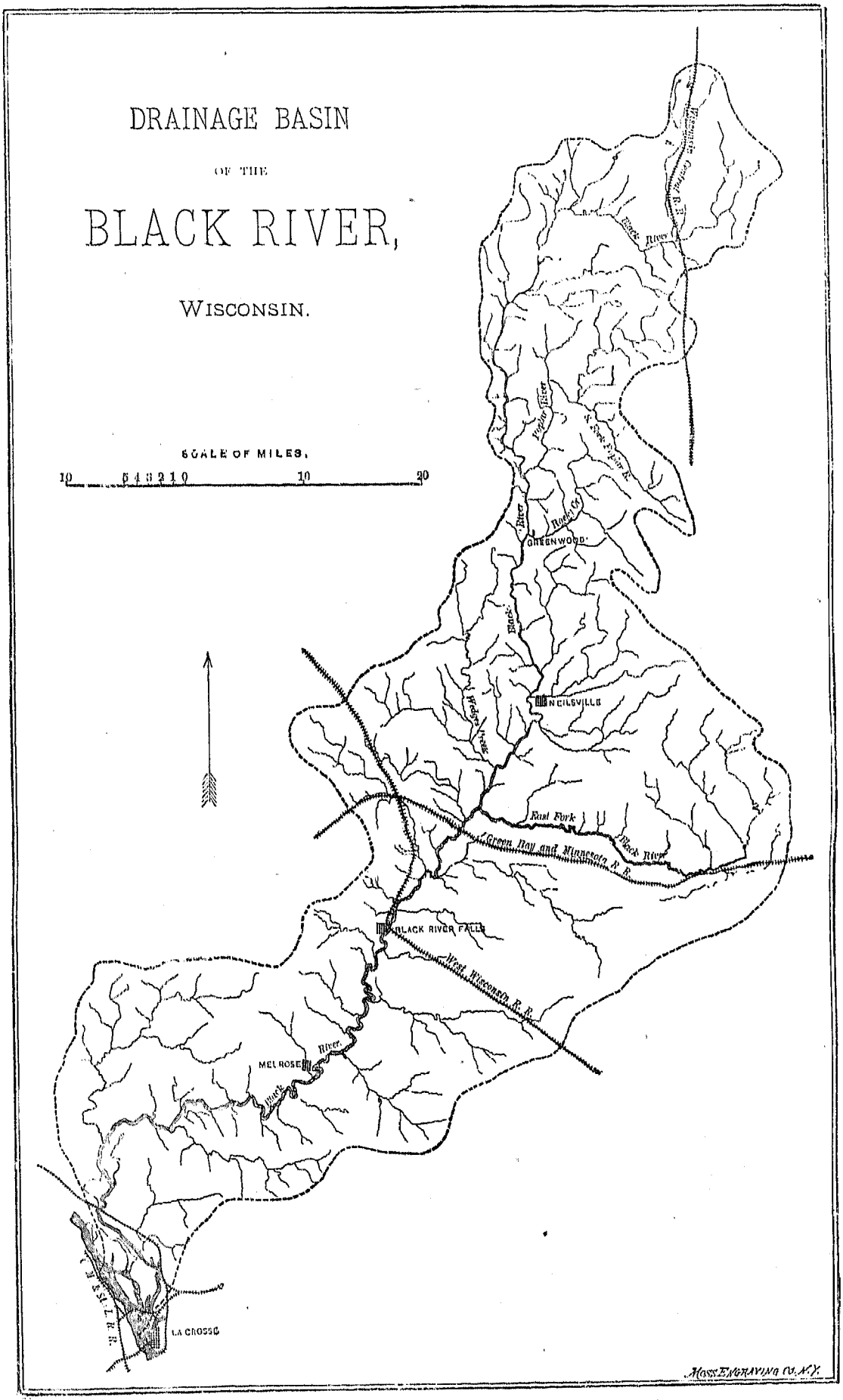
The drainage-basin partakes, of course, of the same general character possessed by the basins on each side of it. The southern portion of the pine region crosses the basin between 60 and 80 miles from the mouth of the river, and all the upper half is pretty much covered with timber. Along the lower portion of the river the country has more of the open nature characteristic of the lower part of the Chippewa basin. The soil there is heavier, containing more clay, but in the pine region there are sand ridges. These are sometimes replaced by a heavier clay soil, as is the case in the neighborhood of Neillsville, 85 miles from the mouth of the river. The rich soil there makes excellent farming land, grows fine hardwood timber, and the transition to the sand ridges lying east is very apparent. The surface of the basin is either level or rolling.

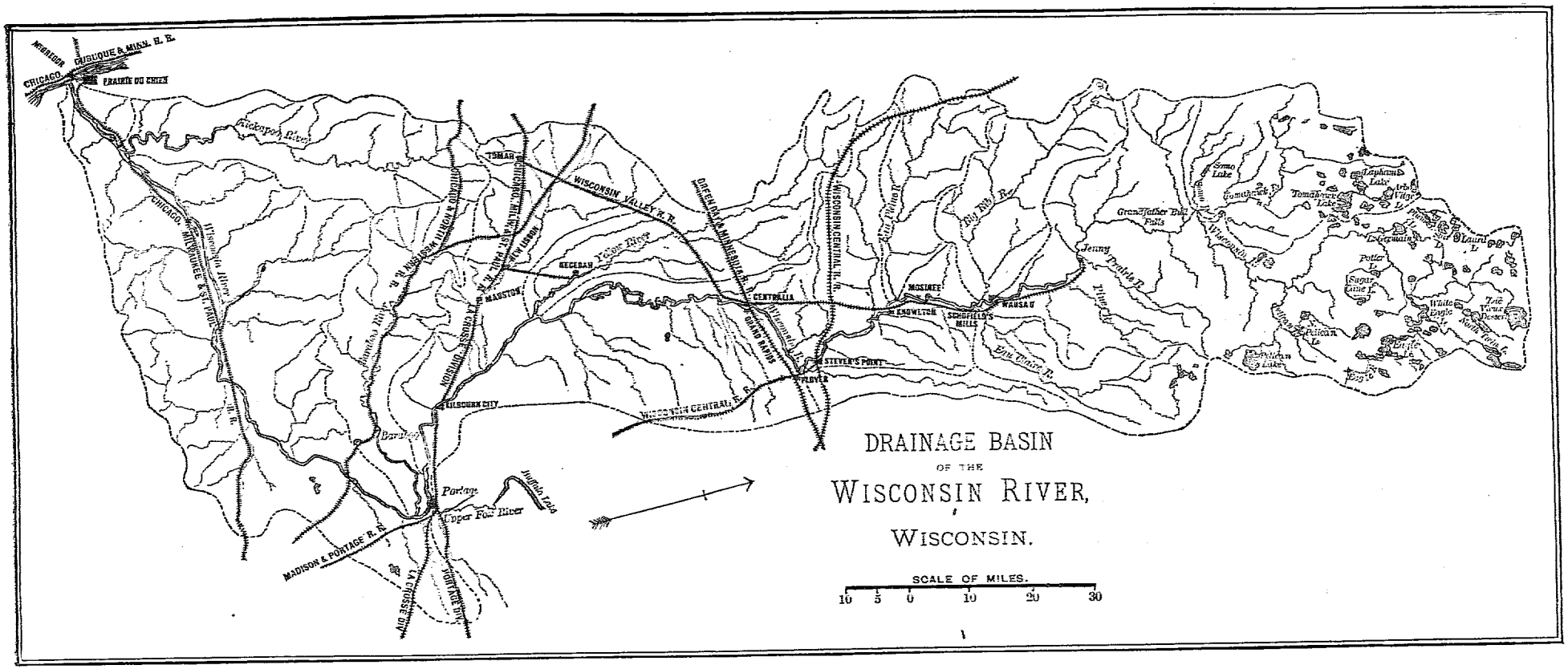
Lumbering has been the great business along the river, and for 17 years the average yearly cut has been 140,000,000 board feet. All the fine pine now standing is on the upper waters, and it is considered that it will not last much over five years longer, but there is a vast amount of inferior timber yet to be taken. Poplar wood occurs in large quantities.

All the country about the lower portion of the river is pretty well settled and under cultivation. The principal towns are Black River Falls, about 60 miles from the mouth, and Neillsville, which is a short distance back from the stream, and about 85 miles above its mouth.

The two railroads crossing the basin are the Chicago, Saint Paul and Minneapolis, which crosses the Chippewa at Eau Claire, and the Black river at Black River Falls; and the Green Bay and Minnesota railroad, which crosses the Black river about 11 miles above Black River Falls. There is a branch from this latter road running to Neillsville.

There are a few lakes at the upper waters, but the basin is not very well supplied with these natural reservoirs, and if it were not wooded and largely covered with a porous soil its streams would be very unsteady, especially


DRAINAGE BASIN
OF THE
BLACK RIVER,
WISCONSIN.
SCALE OF MILES.
10 5 4 3 2 1 0 10 20
Black River
Popple River
Rock Cr.
GREENWOOD
Black
Wedges Creek
GILSVILLE
East Fork
Green Bay and Minnesota R. R.
Black River
BLACK RIVER FALLS
West Wisconsin R. R.
MELROSE
Black River
LA CROSSE
Mass. Engraving Co. N.Y.


MERIDIAN
DUBUQUE & MINN. R. R.
CHICAGO
PRAIRIE DU CHIEN
Rickapoo River
TOMAH
WISCONSIN VALLEY R. R.
CHICAGO, MILWAUKEE & ST. PAUL R. R.
CHICAGO & NORTH WESTERN R. R.
Wisconsin River
REEDSBURG
Yellow River
MARSTON
MINNEAPOLIS & ST. LOUIS R. R.
Baraboo River
DODGE, LA CROSSE & MINNESOTA R. R.
CENTRALIA
GRAND RAPIDS
WISCONSIN CENTRAL R. R.
Little Plover R.
Big Eau Pleine R.
MOSINEE
KNOWLTON
SCHOFIELD'S MILLS
WAUSAU
Jenny Prairie R.
Pine R.
STEVEN'S POINT
PLOVER
Big Plover R.
WISCONSIN CITY
Baraboo
Portage
Buffalo Lake
Upper Fox River
MADISON & PORTAGE R. R.
LA CROSSE DIV.
PORTAGE DIV.
Grandfather Falls
Tomahawk Lake
Lac Vieux Desert
Pelican L.
DRAINAGE BASIN
OF THE
WISCONSIN RIVER,
WISCONSIN.
SCALE OF MILES.
10 5 0 10 20 30

on account of its long, narrow form. As it is, the Black river has the reputation of rising and falling rather rapidly, but it maintains its flow fairly during low water.

There are a number of logging-dams on the river, and if these were controlled in the interests of water-power they would aid very materially in regulating the flow. This can probably be done in the future if the demand for power be sufficient. The low water, as with the other rivers of the region, is usually for about a month, in July and August and during severe winters. At an average section of the bed the ordinary rise is about 6 feet, and a rise of 18 feet is a very unusual one.

Between Black River Falls and Neillsville the channel is from 150 to 250 or 300 feet wide during a fair stage of water. The source is stated in the *Geological Report of Wisconsin* to be between 1,300 and 1,400 feet above the sea, and hence the total fall of the river must be about 750 feet, or over 4.5 feet per mile. The slope is less below Black River Falls than above, and at that place is the last appearance of the hard metamorphic rock in the river. Below it flows through the sandstone region, while above it is described as being "constantly broken by chutes and rapids over gneiss and granite". Owing to the form of the basin the flow must diminish rapidly toward the source, and hence also the power for a given fall. At the mouth the area tributary to the river is 2,272 square miles; at Black River Falls it is 1,569 square miles, and at Neillsville, only 25 miles above, it is only 729 square miles.

There are no tributaries of special importance, as might be inferred from the shape of the basin. The largest is the East fork, which enters the river about half-way between Neillsville and Black River Falls, and drains 305 square miles in the eastern projection of the basin; all the other side streams fall far short of this in extent of drainage area. The tributaries of the Black river are characterized by many rapids and moderate falls, and there are some small flouring- and saw-mills upon them.

POWERS ON THE MAIN STREAM.

Some years ago there were several saw-mills run by the power of the Black river, but there was a lack of capital to construct booms, etc., sufficient to withstand the freshets on the river, and the mills have been nearly all abandoned.

There are only three points on the river at which power is utilized at present. These are Black River falls, Greenwood (some 15 miles above Neillsville), and a point 4 miles above Greenwood. At Greenwood and the privilege above there are, according to the census returns, a grist-mill using 85 horse-power under a head of 17 feet, a saw-mill using 48 horse-power under a head of 17 feet, and a small saw-mill using 15 horse-power under a head of 12 feet.

BLACK RIVER FALLS.

At Black River falls there are very heavy rapids for a short distance over hard granite rock. At the right hand of the main channel, which is about 150 feet wide, is a small island, and at its head is a low dam, extending across the main channel, and turning the water to the manufactories situated on the island and right-hand shore. These are a flouring-mill of 150 horse-power, a saw-mill of 150 horse-power, and a sash and door factory of 75 horse-power, all running under a head of 10 feet. These are all owned by one person, who has the right to 2,500 "inches" of water at all seasons, and 5,000 "inches" when the river is at a stage of 1 foot above low water. The remaining power belongs to another owner, but is entirely unemployed. There is room for utilizing the full power of the stream, but the head cannot be increased by raising the dam, as it would flood up on streams where there are mills. There is, however, considerable fall unimproved below the dam. From the angles in the rock, and its compact, hard nature, it seems probable that valuable granite quarries could be opened at Black River falls, very near the railroad.

Unemployed power.—So far as could be ascertained, there is no practically available power found on the river above the mouth, until within a mile of Black River falls, where 9 feet of fall could be obtained.

The next place is 2 miles above Black River falls, where 10, 15, or even 20 feet of head is available, according to the height of dam built. From there up to the Dells dam, 14 or 15 miles above, there is a heavy fall, and available power at a great many localities. The Dells dam is used for logging purposes.

From the dam up to 3 miles below Neillsville, a distance of about 6 miles, there is no available power, but above that, up to the source, there is a rapid slope in the stream and much available power.

At the rapids in the Black river the bed and banks are usually of granite rock, and the situations are many and excellent for utilizing the power.

WISCONSIN RIVER.

The Wisconsin river has the largest drainage area of all the rivers of the state of Wisconsin; and in the sense that the Minnesota is *the* river of Minnesota, so can this river claim the title of *the* river of Wisconsin. The inhabitants of the region frequently dub it "the Old Wisconsin".

The river rises in Lac Vieux Desert, a sheet of water some 10 square miles in extent, lying directly on the line separating the upper peninsula of Michigan from Wisconsin, and after a course of about 400 miles, enters the

Mississippi just below Prairie du Chien, and 40 miles above the southern boundary of the state. The general course of the river is nearly directly south for about 300 miles, to Portage City, and then it turns sharply, and flows west and southwest for the remainder of the distance to its mouth.

Description of the basin.—The drainage basin of 12,280 square miles has an average width of about 50 miles, and is 225 miles long. The river flows, for the most part, in the eastern half of the basin, and below the bend at Portage it follows within about 10 miles of its southern edge. At Portage the line of water-shed, if it can be said to exist there at all, passes within a mile east of the river, a peculiarity to be referred to farther on.

The long and narrow basin of this river extends in a south-southwest direction nearly across the state, and illustrates, more fully than either the Chippewa or Saint Croix basins, the main topographical features already discussed when treating of those rivers. There is the same wooded (pine) region, extending from Michigan down to within about 40 miles by river of Portage city; below that the pine disappears, and a semi-prairie region gradually takes the place of the woods, the same as in the Chippewa and Saint Croix basins. The country is undulating, and in places decided ridges break the surface. In the southern part of the basin the Baraboo ranges of quartzite pass east and west, from 400 to 700 feet above the surrounding country, and form a striking feature of the scenery. The bluffs along the lower river, especially on the south side, rise several hundred feet, forming prominent ramparts to the valley. Back from these the country is level or undulating.

In the northern portion of the basin are many lakes and tamarack swamps, like those which characterize the headwaters of the Chippewa, being in fact but a continuation of the same system; and all the way down to Portage there is more or less swamp land between the ridges. The soil in the lower portion of the basin is heavier, containing more clay than in the pine regions, where a light, rich loam supports the heaviest growth of pine; and where in some places sand is a chief constituent of the ridges.

The lower half of the basin is pretty well settled, and the advance posts are rapidly passing up into the region to the north. Lumbering has been the chief business on the river, but the center of the lumber interests is moving up-stream toward the headwaters, and, as with the other rivers, the good pine is fast disappearing. The principal towns on the river above Portage are Grand Rapids, about 90 miles above, then Stevens Point, 20 miles farther up, then Wausau, 45 miles above Stevens Point, and finally Jenny, about 20 miles above Wausau. All these towns have saw-mills, and owe their existence to the lumber trade. The lower ones are gradually drawing other branches of industry within their limits, and are becoming centers of trade for the surrounding population; but those farther up the river, as Jenny and Wausau, have yet to pass from the first stage in their history.

Numerous railroads cross the lower half of the basin, belonging chiefly to the Chicago, Milwaukee and Saint Paul, and the Chicago and Northwestern companies. The Wisconsin Central has its line to Saint Paul, crossing the river at Stevens Point, and the Green Bay and Minnesota railroad crosses the river at Grand Rapids, striking the Mississippi at La Crosse; and, finally, there is the Wisconsin Valley railroad, which, starting from the Chicago, Milwaukee and Saint Paul at Tomah, runs north, crossing the river at Knowlton, about 20 miles above Stevens Point, and then running along its east side to Jenny, the present terminus of the line. About 6 miles above Knowlton it passes by Mosinee, a lumbering town. These railroads in the lower part of the pine regions are now used very extensively for shipping lumber, and the statement was made that probably not more than one raft passes down to Portage now, for twenty that used to pass down the river in former years. This decrease is not due to a decline in the lumber trade, but to the change in the method of transfer.

Geology of the river.—Like all the large rivers of the state, the Wisconsin heads in the high drift region underlaid by the primitive Archæan base of the continent, and flows south over successive strata of sedimentary rock to the mouth. This has led to its division into two sections. The upper one is the Archæan region, in which in many places the bed is worn through the drift and down to the hard metamorphic rock, which, presenting a barrier to further erosion, causes numerous rapids. This section ends at Point Basse, about 8 miles below Grand Rapids, where the last outcrop of granite is found in the bed of the stream. Then begins the second section, in which the river has found a more yielding material into which to cut its bed. This is largely the Old Potsdam sandstone, and the disintegration of this has made the bed of the river one succession of shifting sand-bars, almost without interruption, to its mouth. Where it is near the surface in the surrounding country, the soil is very light, and even sterile in places.

For a distance of 7.5 miles, ending at Kilbourne City, which is about 21 miles above Portage, the river flows through what are known as the Dalles of the Wisconsin. Like the Dalles of the Saint Croix, they consist of a narrow gorge through which the river passes, but instead of rocky cliffs of trap, the walls have been carved out of the Potsdam sandstones 50 or 100 feet high, evidently by the river itself. Above the Dalles the river is over a third of a mile wide, but it immediately narrows down to 200 feet, which is its average width through them. In one place it is only 50 or 60 feet wide. The softer character of some of the sandstone layers has caused unequal erosion, and some very singular and picturesque forms have been given to the cliffs, making the Dalles a great resort for tourists and pleasure parties.

From a short distance below Portage, down to the mouth, the river valley is characterized by bluffs, which gradually increase in height, until near the foot of the river they have the full height of those bordering the Mississippi trough. They often rise on the south side 300 or 350 feet above the valley, nearly vertical. They are formed by the projecting edge of the Lower Magnesian limestone, which, acting as a high barrier, has forced the river to flow westward until it found a passage in the deep trough of the Mississippi.

Mention has been made of the Baraboo ranges, which consist of two ridges of quartzite extending east and west in the section of country west of Portage. They are from 4 to 6 miles apart, about 25 miles long, and unite in an abrupt headland in the bend of the Wisconsin opposite Portage, where they end. Between them is a depressed area. It is apparent that the bend of the river to the eastward and then west, is due to the effort to find a passage around this rock barrier. Above Portage the river has been found fully large enough to account for its valley, while below it is much like the Minnesota river, lost to a certain extent in the big trough through which it flows. The reasons for this peculiarity, as obtained from the *Geological Report of Wisconsin* have been briefly given in treating of the Fox River basin, and are these:

Change in the drainage system.—The line of water-shed on the east side of the river at Portage can scarcely be said to exist; a low sandy plain not more than 2 miles wide, and only elevated a few feet above the river, is all that separates it from the upper Fox, which flows northeast, uniting with the Wolf river, and then flowing north to lake Michigan.

At places this plain is highest nearest the Wisconsin, and in high water the overflow of the Wisconsin causes freshets on the upper Fox. It is evident that such an uncertain divide as this cannot have formed one of the original permanent features of the drainage of the region, but as the disposition of the surface soil is due to glacial action, modified, it is true, by subsequent erosion and transportation, this may be fairly attributed to such a cause. The rampart of limestone which compels the lower Wisconsin to flow west, does not stop south of Portage, but continues east and north, although less prominent, forming an eastern barrier to the flow of the Wolf river. The course of the upper Fox to lake Winnebago is sluggish, consisting largely of marsh and lake-like expansions. On account of the depression of the divide at Portage, the continuation of the southern barrier northeast, the small slope of the upper Fox, the large trough of the Wisconsin below Portage, which it is unable to occupy, while above the river is more nearly in proportion to its channel of drainage, and finally the evidently modern outlet for the Wolf and the upper Fox through the lower Fox river—the conclusion is reasonable, if not inevitable, that at one time the lake Winnebago system drained southwest into the Mississippi, and the Wolf river was the true continuation of the Wisconsin above Portage, while the present upper Wisconsin was merely a tributary of the main stream. During the changes incident to the deposition of the drift, the channel was choked up, and partly owing to this, perhaps also due to a change in elevation, as suggested by General G. K. Warren, the drainage was directed to lake Michigan.

The records left on the face of the country afford an interesting insight into the past history of that tributary stream which now forms the upper portion of the Wisconsin river. It has been mentioned that it is deflected to the east by the Baraboo range, passing around the eastern outpost at Portage. There is a deep gorge cutting south through the ranges, entering the Wisconsin valley near Sauk City, some 25 miles below Portage. This has been largely filled with drift, and two immense heaps dam up the gorge, forming Devil's lake, with its wild, romantic scenery. It is thought that this gorge was at one time the channel of the river, but being choked with the material carried down by the glaciers, the river was deflected and compelled to seek a new channel around the ridge.

Table of distances, flow, etc., of the Wisconsin.

Station.	Distance from preceding station. (a)	Distance from source.	Drainage area above station.	Flow per second past station.		Theoretical horse-power under 10 feet head.	
				Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Miles.*	*Sq. miles.*	*Cu. feet.*	*Cu. feet.*	*H. P.*	*H. P.*
Above mouth of Pelican river	60	60	940	307	872	416	980
Mouth of Pelican river	0	60	1,202	469	1,115	532	1,265
Mouth of Tomahawk river	25	85	2,111	823	1,959	934	2,222
Mouth of Prairie river	28	113	2,877	1,122	2,670	1,273	3,029
Above mouth of Rib river	23	136	3,102	1,245	2,962	1,412	3,360
Mouth of Rib river	0	136	3,690	1,439	3,424	1,633	3,771
Mouth of Eau Claire river	2	138	4,114	1,604	3,820	1,820	4,334
Above mouth of Eau Pleine river	20	158	4,268	1,664	3,961	1,888	4,495
Mouth of Eau Pleine river	0	158	4,645	1,811	4,311	2,055	4,881
Mouth of Little Eau Pleine river	8	166	5,005	1,952	4,645	2,215	5,270
Mouth of Plover river	18	184	5,300	2,067	4,918	2,345	5,580
Above mouth of Yellow river	64	248	6,448	2,513	5,984	2,851	6,789
Mouth of Yellow river	0	248	7,394	2,884	6,862	3,272	7,785
Mouth of Lemonweir river	11	259	8,172	3,187	7,584	3,616	8,604
Mouth of Baraboo river	33	292	9,095	3,547	8,440	3,024	9,575
Above mouth of Kickapoo river	97	389	11,387	4,440	10,567	5,037	11,988
Mouth of Kickapoo river	0	389	12,150	4,742	11,284	5,381	12,702
Mouth of Wisconsin river	18	407	12,280	4,784	11,386	5,427	12,929

a Map measurement above Baraboo river.

Tributaries of the Wisconsin.

River.	Length (map measurement).	Drainage area.	Discharge per second.		Theoretical horse-power under 10 feet head.	
			Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Sq. M.*	*Cu. feet.*	*Cu. feet.*	*H. P.*	*H. P.*
Pelican river	25	262	102	243	115	276
Tomahawk river	50	714	278	664	315	753
Rib river	50	498	194	462	220	524
Eau Claire river	50	423	165	383	187	435
Eau Pleine river	50	377	147	350	167	397
Yellow river	70	946	369	878	419	996
Lemonweir river	50	588	229	540	260	619
Baraboo river	70	655	255	608	288	690
Kickapoo river	75	760	296	705	336	800

Hydrography.—Owing to the form of the basin and to the course which the river takes through it, there are no very large tributaries. The drainage basin is pretty well distributed among the different branches, and the drainage falls into the stream quite regularly in proportion to its length from north to south. The principal exception to this is in the case of the Yellow river, the largest tributary, which makes some 60 miles of southing before it reaches the Wisconsin. The principal branches from the source down are the Tomahawk, or Little Wisconsin of some maps, with 714 square miles drainage area; the Rib river, 498 square miles; the Eau Claire, and Eau Pleine, each draining less than the Rib river; the Yellow river, 946 square miles; the Baraboo, 655 square miles, and the Kickapoo, 760 square miles.

Flow.—The wooded character of all the upper portion of the basin, the swamps and lakes, and the porous nature of so much of the soil, all act, as in the case of the Saint Croix and the Chippewa, to maintain the flow of the river during dry and cold seasons, and make the Wisconsin one of the steadiest, if not the most uniform, in flow of all the large tributaries of the upper Mississippi. As nearly as can be ascertained from gaugings and from comparison, the average ordinary low flow is 0.39 cubic foot per second per square mile, an amount greater than in the case of the sources of the Mississippi; but it must be remembered that the rainfall per year averages about 35 inches.

In calculating the flow at various points for the accompanying tables, the average factors for the entire basin have been used throughout, although some of the tributaries undoubtedly have a more uniform flow than others. The river is considered a steady stream by those using its water-power. The ordinary rise at Jenny is about 6 feet above low water, and at Grand Rapids a rise of 8 or 10 feet above low water is considered very high.

Surveys have been made at the sources for reservoirs. The basin does not appear to afford so many available holding-grounds as those previously discussed, and it is not thought that any will be found on the main stream below the mouth of the Tomahawk. Above that there have been eight surveyed, which can be developed at a cost of about $200,000, and it is estimated that they would add a discharge of 2,300 cubic feet per second for ninety days during the summer to the low discharge of the river, which is about 5,000 cubic feet per second.

It is perhaps proper to mention in this connection the system of navigation from lake Michigan to the Mississippi by means of Green bay and the Fox river to Portage, and then down the Wisconsin to the Mississippi. This has been described in the report on the Fox river, and will not be dwelt upon now further than to state that practically it is of no use except for local trade on the lake Michigan side of the divide. The extremely unstable nature of the bed of the lower Wisconsin renders it a most difficult engineering feat to maintain a navigable channel, which has not yet been accomplished, and probably will not be enforced without great expense. It was proposed by General Warren to leave the river entirely and construct a canal along its valley to the Mississippi. On the lake Michigan side the character of the streams admits of the comparatively easy maintenance of a navigable course.

Fall of the main river.—Lac Vieux Desert is near the high divide separating the lake Superior drainage from that flowing south, and at an altitude of 1,532 feet above the sea. The mouth of the river is about 600 feet above sea-level, and hence in its course, estimated to be 407 miles, it falls 932 feet, an average of 2.29 feet per mile. The elevation of the river at Kilbourne City, at the foot of the Dalles, is 814 feet above the sea; hence, in the distance of 140 miles to the mouth, the total fall is 214 feet, or 1.53 foot per mile. Below Portage it is 1.5 foot per mile, as ascertained by General Warren's survey. Above Kilbourne City the total fall is 718 feet in a distance estimated to be 267 miles, or 2.69 feet per mile. Above Grand Rapids the total fall is, approximately, 530 feet in a distance of 200 miles, and the average slope is 2.65 feet per mile.

About 10 miles below Grand Rapids is Point Basse, which marks the southern limit of the Archæan section of the river, and in this distance are heavy rapids. It is evident, then, that the most rapid part of the river is in the

Archæan section, and here, with one exception, are the available water-powers. Above Wausau the slope is 2.45 feet per mile, but between Grand Rapids and Wausau it averages about 3.12 feet per mile; and it is in this distance of about 66 miles that the bulk of the available power is situated. Although there are numerous rapids available above Wausau, one very extensive one is yet to be mentioned.

The bed of the river is rock at the rapids, but at intermediate places it is largely made up of sand, gravel, and bowlders. The situations are fine for the development of water-powers, and the existing dams do not flood any considerable extent of land. These dams are the ordinary log constructions known as "spar-dams".

The amount of information obtained regarding the extent of the rapids of the Wisconsin is limited. According to the reports of the United States engineers there are some rapids at the mouth of Eagle river, about 24 miles below Lac Vieux Desert, called Otter rapids. It is proposed to build a dam at the head of these rapids, creating a reservoir, and it is said that "the water can easily be raised 22 feet". From the head of the rapids down to about a mile above the mouth of Pelican river, a distance of about 35 miles, the total fall is stated in the above report to be only 57 feet, or about 1.63 foot per mile; but those familiar with the river state that there are numerous small rapids and much available water-power down to near Jenny, where the heavy rapids begin. The entrance of the Tomahawk river increases the tributary area from 1,397 to 2,111 square miles, and adds very materially to the volume of the main stream.

In the section from 15 miles above Jenny down to Point Basse there are seven principal rapids, namely, Grandfather Bull rapids, Big Bull rapids at Wausau, Little Bull rapids at Mosinee, Stevens Point rapids, Conant's rapids (just below the last place), Grand Rapids, and Whitney's rapids at and above Point Basse. Some of these are very heavy. Grandfather Bull rapids, which are 15 miles above Jenny, are the heaviest rapids of the Wisconsin, the total fall being 105 feet in a distance of 1⅛ mile. The river is about 500 feet in width, and divided at the head of the rapids into three channels by two rocky islands, which rise 10 or 15 feet above the water and extend some distance down stream. The bed and the banks of the river consist of varieties of granitic rock. The descent is largely distributed in small falls from 2 to 7 feet and from 150 to 300 feet apart.

There are two small rapids 6 and 12 miles, respectively, above Grandfather Bull rapids, and at Jenny are Beaulieux's rapids, now improved. Below are Trap rapids and then Wausau. The section 25 miles long from Wausau to Knowlton, below Mosinee, has an average descent of about 4 feet per mile, and the greater part of the fall is concentrated in Big Bull rapids. From Knowlton down to Stevens Point the total fall is 30 feet in 20 miles. In the 20 miles from Stevens Point to Grand Rapids the total descent is 64 feet, or 3.2 feet per mile, and this includes Conant's rapids, which are said to have a fall of some 30 feet in 2 or 3 miles. For the last 15 miles above Point Basse there is a long series of rapids with intervening reaches of quiet water. The amount of descent in this distance is not known. These rapids, included in the Archæan region, are over hard metamorphic rock, which furnishes excellent foundations for dams and other structures.

Improved powers.—There are in all six improved powers on the Wisconsin, all between Jenny and Point Basse, in the order given below. A personal visit was made to Jenny, Stevens Point, and Grand Rapids; for the other rapids between these places information was obtained by interview:

Jenny.—The first is at Jenny, where on the left bank is a saw-mill, using 260 horse-power, and on the right bank a grist-mill, using 50 horse-power, both under a head of 11 feet.

Wausau.—At Wausau there are a number of rocky islands, composed of syenitic granite, between which the water rushes in heavy rapids, forming Big Bull rapids. The dams cross to the islands, and a head of 12 or 13 feet is used. There are three saw-mills, each with four circular saws, a gang-saw, and a planing-mill attached. There is also a grist-mill with four runs of stones. The total power used is about 500 horse-power.

Mosinee.—At Little Bull rapids the river is divided into two channels by a rocky island, about a quarter of a mile wide. The main portion of the river passes through the eastern channel, which is stated to be only 35 feet wide for a distance of 135 feet. The rock is syenite. The water is carried down the island in a race, and supplies a saw-mill, a planing-mill, a grist-mill of two or three runs, and a small tannery, under a head of about 12 feet. The total power used is about 200 horse-power.

Stevens Point.—At Stevens Point the river is about 600 feet wide, which is above the average. The dam extends all the way across the channel, and the mills are on the left bank. They comprise a saw-mill directly at the dam, and a grist-mill adjoining; also a flouring-mill, about 200 feet back from the river-bank. The head used is 6 feet at all the mills.

The power originally belonged to a person connected with the saw-mill. He sold 4,000 "inches" of water to the flouring-mill, but still retains the remaining flow of the river. The saw-mill has three wheels, using altogether 3,700 "inches" of water; the grist-mill has two wheels, with a combined capacity for 1,500 "inches"; and the 4,000 "inches" owned by the flouring-mill drive three runs of stones and two sets of rollers. The total flow disposed of is, consequently, 9,200 "inches." The owner of the unemployed power considers that only about one-third of the low-water flow of the river is in use. According to the method of estimating discharge, 9,200 inches under a head of 6 feet gives a flow of 1,250 cubic feet per second. Adopting the ordinary low flow of 0.39 cubic feet per second per square mile for the area above Stevens Point, gives a volume of flow of 1,970 cubic feet per second.

The bed and banks of the river are solid rock, consisting chiefly of gneiss. There are rapids below the dam, and probably at least 2 feet of additional fall is available down to the railroad bridge, which crosses the river some 1,500 feet below. Each bank is flat, and apparently in excellent condition for extending a race down it. Five or six feet is a very high rise in the pond, but this is a wide place in the river. A side-track from the railroad passes near the mills on its way to the steam saw-mills, a third of a mile up-stream.

Just below Stevens Point begin Conant's rapids. They are unimproved, but afford many good sites to be developed. As before mentioned, there is a reported fall of about 30 feet in a distance of 2 or 3 miles. The rock consists chiefly of varieties of gneiss and syenite.

Grand Rapids.—The town of Grand Rapids is situated on the left or east bank, and Centralia is directly opposite. The rapids extend about half a mile below, and for about 3 miles up-stream there is more or less rapid water, but the main rapids are at the towns. There, for a distance of about a mile, from the Green Bay and Minnesota Railroad bridge down to the highway bridge between the two towns, the river spreads out to a width of about 1,000 feet, and rushes down between rocky islands and spurs of gneiss rock, with an estimated total fall of 25 feet. All the power used is on the Centralia side of the river, where there are a flouring-mill, a saw-mill, and a shingle-mill. In former years, when Grand Rapids was in the center of the lumber trade, there were mills on the east side of the river, and the ruins of an old race, a saw-mill, and one or two other buildings yet remain.

This power on the Grand Rapids bank could be once more improved. The bank is rocky, and rises steeper than on the other side, but would not prevent the utilization of the power. On the west or Centralia side there is a good level bank, and the full resources of the place could be improved. At present there is only about 300 horse-power in use, of which the flouring-mill takes 150 horse-power under a head of 11 feet, the saw-mill 100 horse-power under the same head, and the shingle-mill 50 horse-power under a head of 8 feet. The flouring-mill has six runs of stones and several sets of rollers. The wheat and corn are obtained chiefly from Minnesota and Iowa.

It has been proposed to build a paper-mill at Centralia, and undoubtedly if this is done a pulp-mill would form part of the establishment. There are great quantities of poplar wood growing along the Wisconsin and its tributaries which would be of value to the paper manufacture.

The river above the railroad bridge consists of several channels, and of these it is the one furthest west which supplies the water-power at Centralia. This power is owned by the proprietor of the mill at that place, and it is claimed that about one-half the ordinary discharge of the river passes through this west channel. This would give, according to our estimates, an ordinary low flow of 1,043 cubic feet per second, which under a head of 25 feet gives 2,960 theoretical horse-power.

Port Edwards.—The next and last improved power on the river is at Port Edwards, about half way between Grand Rapids and Point Basse. Mention has already been made of the succession of rapids and slack-water in that locality; and there is, undoubtedly, a great amount of power available in addition to the small amount used by the one saw-mill there, which takes 500 horse-power under 10 feet head of water.

At Point Basse is the limit of the region of rapids, and the river enters upon the lower section, where it flows over softer sedimentary rocks. So far as could be ascertained, there is no really available site for water-power in the entire distance down to the mouth, with the exception of the Dalles.

Water-power at Kilbourne City.—Kilbourne City is at the lower extremity of the Dalles of the Wisconsin, and at this point there is an available power, which was at one time in use, the nearest to the mouth of all the water-powers on the river.

Seven or eight hundred feet below the Chicago, Milwaukee and Saint Paul Railroad bridge the river takes a bend to the east, and emerges from the Dalles, which there consist of cliffs of light-yellow and gray sandstone from 30 to 50 feet high. The channel of the river is 400 or 450 feet wide at the bend.

A few rods above the bend are the remnants of an old dam, over which the water rushes in strong rapids, a favorite resort of the Indians, who at the proper season come long distances to spear sturgeon for their winter's food.

The history of this old dam is as follows: About 1857 a charter was obtained for the erection of a dam at this point, with a height of 3 feet above low water. It was erected with a height of 8 feet. Subsequently part of it was washed out and was afterward rebuilt. The rafts were badly broken up in passing over the dam, and finally a large party of lumbermen came down-stream in force, and by cutting and blasting succeeded in tearing away all the dam down to low-water mark. About 1866 the dam was rebuilt with the 3-foot head allowed by the charter, and a flouring-mill erected on the east bank of the river directly at the abutment of the dam. This was burnt by incendiaries, and since then nothing has been done with the power. The greatest opposition was from the Yellow River lumbermen; their rafts had no dams to pass except this one, and hence were not so well provided with spring-poles, etc., as those from farther up the river; consequently, they were very liable to be destroyed.

Since the introduction of railroads most of the lumber is shipped by them, and so few rafts pass down the river that it is thought little objection would be now raised to the utilization of the water-power. The situation is excellent as regards facilities for transportation, because of the vicinity of the railroad.

Although the original head allowed by charter was only 3 feet, it is probable that little objection would now be made to raising the dam so as to give a head of 8 feet or even more, which is possible, as the raising of the dam

would merely back the water up the Dalles. The dam as it now exists could be made the foundation for a new one. By building a bulkhead at the east end, where the wheels of the old mill were placed, it is probable that the 3-foot head could be restored with a cost of from $1,000 to $2,000.

The dam was so substantially built as almost to defy the efforts of the lumbermen to destroy it. The following description was given of its construction: First, a crib of oak timber, dovetailed together, 80 feet wide at the base, 10 feet high on the lower side, and only 2 feet or so high on the upper side, was built across the river on the ice, steadied with poles, and then sunk with stones into its place. Then on the crib were laid oak trees in rows with their branches on, the butts pointing down-stream. There were two or three lengths of these in the course, the butts of one length resting on the branches of the other. The course was then weighted with stone, cross-timbers were placed across the rows of butts, and the process was repeated.

The chief disadvantage of the locality is the limited space for utilizing the power. However, the sandstone cliff could be cut away, as was done for the old mill, and a race could be carried along it. This would be expensive, and would only be warranted, if at all, by the erection of large establishments. Part of the power could be now used with comparatively little expense, from the site of the old mill.

TRIBUTARIES OF THE WISCONSIN.

There is considerable power utilized on the branches of the Wisconsin, especially in the southern portion of the basin, where the Baraboo and the Kickapoo, with numerous smaller streams, supply power to a large number of mills. The water-shed line is 200 or 300 feet above the main stream on each side, and as the tributaries have to fall this distance within their comparatively short lengths, they have many rapids and available powers.

The larger tributaries, as measured on the Land Office maps, average 50 or 60 miles in length, and hence have an average fall per mile of 4 feet or more. As with the upper portion of the main river, many of the rapids are over the hard granites and allied rocks which underly that region. The streams in the upper portion of the basin have no developed powers.

TOMAHAWK RIVER

Reservoir surveys have been made on the Tomahawk, and their records make mention of a rapid 1,500 feet above the mouth, where the river falls 19 feet in the course of a mile, and of another rapid 10 miles from the mouth, with a fall of 75 feet in 450 feet. The current of the river is usually swift.

Among the rivers which have been at least partially improved, the Baraboo ranks first, with, according to the census returns, 851 utilized horse-power, and next the Kickapoo, with 567 horse-power.

The Lemonweir river has 186 horse-power in use, the Eau Claire river 120 horse-power, and the Rib river and Little Rib river together are credited with 266 horse-power.

YELLOW RIVER.

The Yellow river has 96 horse-power developed, but there are several small tributaries which have more water-power in actual use. The Yellow river has the greater part of its descent in its upper section, where, like the upper Wisconsin, it flows over the metamorphic rock; near its mouth it runs across sandstone strata and is rather sluggish. There is a vast amount of undeveloped water-power on the stream.

LEMONWEIR RIVER.

The Lemonweir has three flouring-mills, using 50, 34, and 20 horse-power, respectively, under heads of from 5 to 8 feet; and two saw-mills, with 57 and 25 horse-power, and heads of 6 and 8 feet, respectively. The source of the river is a swampy, level region of light soil, with meadow and brush growth, and the stream is considered rather steadier in its flow than the Yellow river.

BARABOO RIVER.

The Baraboo is prominent among the water-power streams of the Wisconsin basin. It rises at an elevation of nearly 1,200 feet, and in the distance of 70 or 80 miles to its mouth falls 400 feet, or about 5.3 feet per mile. The rapid descent gives opportunity for a large number of available powers, and as the stream flows through a settled region, these are extensively used. The Baraboo strikes the northern one of the two eas ward-trending quartzite ranges, called the Baraboo ranges, penetrates it, and, after flowing in the intervening valley for 15 miles, once more passes through the northern ridge, and then enters the plain of the Wisconsin valley near Portage. The hard rock encountered causes many rapids.

The number of establishments using the power of the Baraboo is large, comprising 11 flouring-mills, using 580 horse-power, 5 saw-mills, using 123 horse-power, and 5 miscellaneous establishments, such as machine-shops, furniture factories, etc., using 148 horse-power.

The largest power used by one establishment is 168 horse-power under a head of 10 feet, driving the machinery of a flouring-mill. The highest head used is 22 feet, and the average is from 10 to 12 feet. A fall of 10 feet on the lower part of the river gives about 200 available horse-power.

KICKAPOO RIVER.

The Kickapoo river is the last tributary of any considerable size entering the Wisconsin. There is a large amount of fall in its course, and, as in the case of the Baraboo, the power is extensively utilized. Next to the Yellow river it drains the largest area of all the branches of the main river. There are 8 flouring- and grist-mills upon the river, using 224 horse-power, and 11 saw-mills, using 343 horse-power. The head of water used does not average so high as on the Baraboo, being only about 8 feet, while the greatest head recorded is 12 feet. There are no other industries taking the power of the Kickapoo river.

THE CANNON, ZUMBRO, ROOT, UPPER IOWA, AND TURKEY RIVERS.

Because of their general similarity, the three great rivers of Wisconsin have just been discussed in succession, and now, going back to the west side of the Mississippi, where we left it at the mouth of the Minnesota, the first stream to engage our attention is the Cannon river.

A glance at the map will show that the important streams entering the Mississippi in Minnesota below the Minnesota river are, in order, the Cannon, the Zumbro, and the Root rivers, and, continuing into Iowa, the upper Iowa and Turkey rivers, which last enters the Mississippi below the Wisconsin, about half way between it and the state line separating Illinois and Wisconsin.

Below the Turkey river, in Iowa, are the Maquoketa and the Wapsipinicon, which are reported upon by Mr. Dwight Porter, special agent of the census.

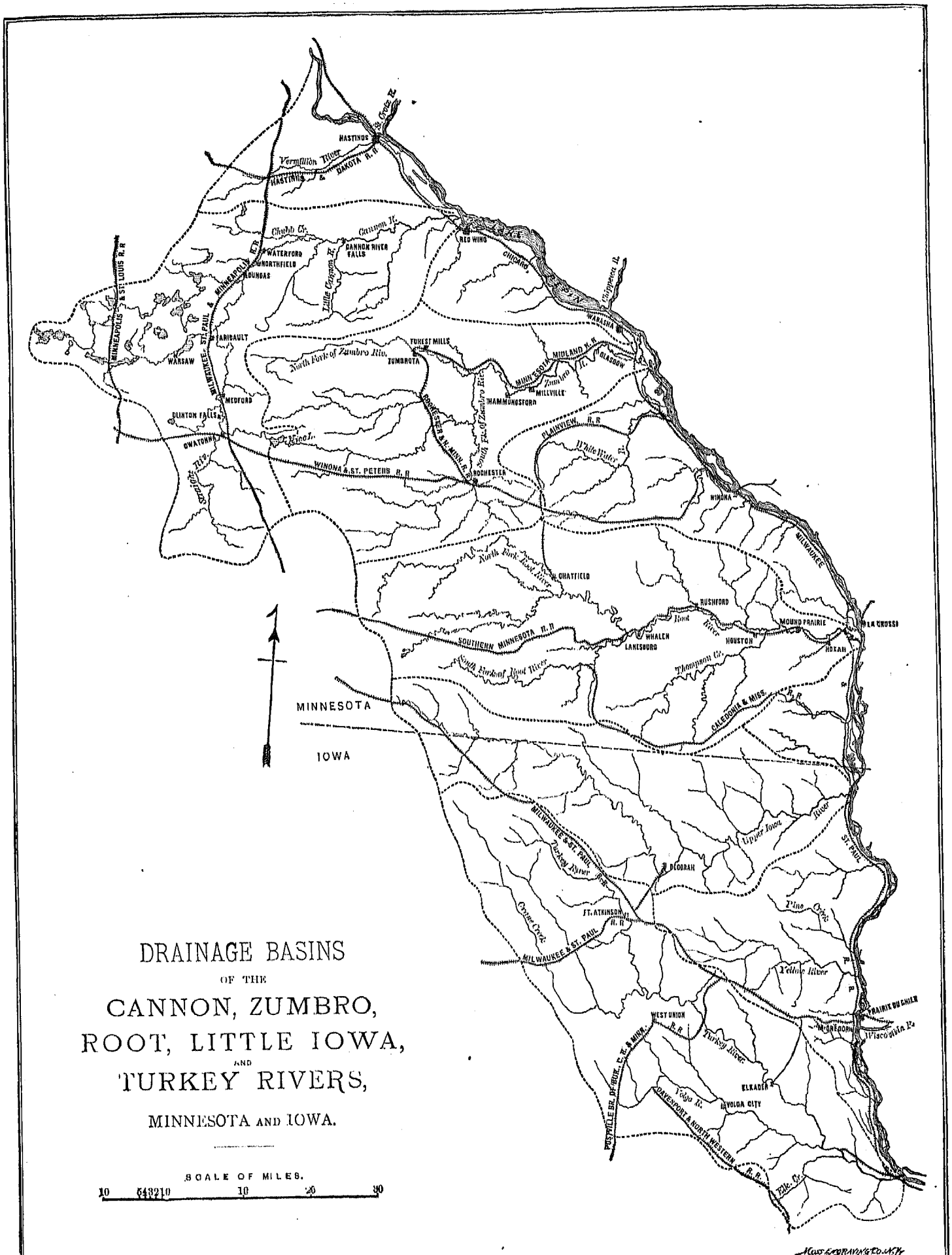
The discussion of the five rivers mentioned at the heading of this section will complete the report on the tributaries of the Mississippi down to the southern limit of the state of Wisconsin, and because of the many characteristics which these five streams possess in common, a general description will apply to all their basins, with a statement afterward of such special details as are available.

GENERAL DESCRIPTION OF THE RIVERS AND THEIR BASINS.

The section of land under consideration is a strip averaging 50 or 60 miles wide, and 150 miles long, extending along the west bank of the Mississippi from the southern line of water-shed of the Minnesota River basin down to the limits of the Maquoketa and Wapsipinicon River basins in Iowa. Of the five rivers which, for the most part, carry its drainage to the Mississippi, the most northern one, the Cannon, has a general northeast direction; the southern one, the Turkey, has a southeast course, while the remaining three, the Zumbro, the Root, and the upper Iowa, flow almost directly east. The drainage area is quite uniformly distributed between them, as shown by the following figures:

	Square miles.
Cannon river	1,492
Root river	1,609
Zumbro river	1,346
Upper Iowa river	952
Turkey river	1,725

As may be inferred from the limited extent of drainage belonging to each of these rivers, they are not of large size, but they derive considerable importance from the extent to which their water-power is utilized, chiefly by flouring-and grist-mills. The census returns show that there is a total of about 9,300 horse-power in use in the region. This is primarily due to the existence of available power, but it is also owing to the condition of settlement of southern Minnesota and Iowa. Numerous towns are scattered over the land, and various branches of the Chicago and Northwestern and of the Chicago, Milwaukee, and Saint Paul railroads run north and west across the region. The land is largely cultivated, and embraces very fertile regions. Most of the winter wheat grown in Minnesota comes from there, and in proceeding south the soil becomes somewhat lighter, assuming more of the characteristics of the loam on which the corn of Iowa is raised. Westward, about the headwaters of the streams, the surface is undulating or only slightly broken by the channels of drainage; but in journeying eastward, toward the Mississippi, a change is noticed; the country is broken, and even hilly, though back from the ridges and bluffs are sometimes extensive stretches of undulating land, and the general level above the valleys is nearly uniform. The small streams, as well as the main rivers, run at the bottom of large valleys several hundred feet deep. These valleys finally unite along the main lines of drainage, and then emerge into the great trough of the Mississippi, 400 or 500 feet, or even more, below the general surface. The succession of cultivated land, prairie, and woodland, broken by the bold bluffs and ridges, presents some of the most charming views of that part of the Mississippi basin. The abrupt hillsides, rising in some places over 500 feet above the Root river, give a character to the scenery along the Minnesota Southern railroad which is a surprise after the experience of the prairie north and west.



DRAINAGE BASINS

OF THE

CANNON, ZUMBRO, ROOT, LITTLE IOWA, AND TURKEY RIVERS,

MINNESOTA AND IOWA.

SCALE OF MILES.

10 5 4 3 2 1 0 10 20 30

Geology.—The geological reports of the three states which meet in this region, especially the reports of Professor N. H. Winchell on the counties in southeastern Minnesota, treat of the topography and its causes.

Frequent allusion has been made to the rib of Archæan rock running east and west, which formed the coast upon which the waves of the Palæozoic ocean used to beat, and to the successive layers of sandstone, limestone, etc., which were deposited from this ocean, and whose successive outcrops are met in passing down the Mississippi. In western Wisconsin and eastern Minnesota there was a deep indentation of the coast-line northward, and consequently the line of strike of the sedimentary rock strata passes northwest and then bends southwest. The first layer above the old metamorphic rock is the Potsdam sandstone, which reaches north almost to the lake Superior trough. Above that, in succession, are the following strata: Lower Magnesian limestone, Saint Peter sandstone, Trenton limestone, Cincinnati shales, Niagara limestone, Devonian, Cretaceous, etc. These strata have a general southern or southwestern dip, and hence in their general relations they are met in their successive order from the Potsdam up in passing south. In the region now under discussion all the strata, from the Potsdam to the Devonian, inclusive, are represented.

The ancient trough of the Mississippi is cut down into the Potsdam sandstone, and the side streams, in reaching it from the west, have worn their beds down through the successive strata of Niagara limestone, Trenton, Saint Peter sandstone, Lower Magnesian, and so on, until they reach the level of the Mississippi. The Mississippi trough passes nearly along the northwest and southeast strike of the strata, and these tributaries from the west pass nearly at right angles across the lines of outcrop. The Turkey river is an exception to this rule; for in its southeast course it follows nearly the line of outcrop, running in the Galena limestone (a division of the Trenton), and sometimes cutting through into the Trenton proper. It is to their erosion in these rocks at the time when the Mississippi was cutting its ancient channel, that the broken country and deep valleys of southeastern Minnesota and northeastern Iowa are due.

In the bluffs which line the valley are sometimes to be seen two or more successive strata through which the river has cut. The hard limestones, underlaid by soft sandstone, have acted to give an abruptness to the cliffs which they would not possess if the erosion had taken place in a homogeneous material. Especially is this true of the Trenton limestone, which, resting on the soft Saint Peter sandstone, has had precisely the effect that is noticed at Saint Anthony falls.

The rapids and finest water-powers generally occur where the streams break across the limestone strata, while in the sandstone regions they have a comparatively uniform slope. Thus most of the rivers are more sluggish near the Mississippi, where they run over the Potsdam sandstone region, and hard rock does not characterize the bed and banks as in the places occupied by the Trenton limestone. These sandy and loam sections of the rivers offer comparatively few advantages in the way of water-power.

The rivers on the opposite side of the Mississippi, the Saint Croix, Chippewa, Black, etc., also have their sandstone sections, but with this difference, that, while the sandstone extends a comparatively short distance up the western tributaries, it appears for many miles up the valleys of the rivers of Wisconsin, practically limiting their available water-powers to the Archæan section. The reason for this is plain: the Mississippi runs near the line of strike of the Lower Magnesian limestone, and leaves to the northeast in Wisconsin a broad expanse of Potsdam sandstone, over which the rivers run with a fall in the direction of the dip. The western tributaries, on the contrary, fall at an angle to the dip of the strata and pass them in a shorter distance.

There is one peculiarity of a large part of the region between the Turkey and the Cannon rivers, which has a very important bearing upon the water-powers. The surface of the northwest was covered with drift during the glacial age—as with a blanket—and to a very great extent all traces of the earlier topography were obliterated, the ancient channels of drainage were filled up, and to this day many of the streams are engaged in re-excavating their beds from the clay, gravel, and sand left by the glaciers.

Although the drift is nearly universal in this region, there is an area in Minnesota, Wisconsin, Illinois, and Iowa known as the driftless region, over which the ice mass did not reach, or the covering of drift spread. It is bounded approximately by a line running east from the mouth of the Chippewa to the Wisconsin, then south and west to the Mississippi, about 15 miles south of the northern limit of Illinois, and then northwest, crossing the upper portions of the rivers we are discussing, and so to the mouth of the Chippewa.

The cause of the glaciers passing around this region is thought by some to have been the projecting rib of hard rock terminating in Keweenaw point in lake Superior, which acted as a wedge to divide the ice mass in its passage south. Professor Dana attributes it to local climatic variations, causing a smaller accumulation of ice.

In the driftless area the lines of drainage and the broader features of the topography remain much as they were before the ice age, and the ragged surface produced by the long-continued erosion of the streams is not rounded off, or completely obliterated by a thick covering of drift. To a certain extent, however, a similar action has taken place. Allusion has been made to the loess, or bluff formation, a deposit of finely comminuted clay and loam settled from the quiet waters of the inland sea which once occupied the basin of the Mississippi. This was deposited to a certain extent over the driftless area, and makes a very fertile soil, but is not thick enough to destroy the ancient topography.

Along the upper waters of the rivers, up to the Cannon, the eastern margin of the drift merges into the loess formation, and west of that the rivers have the characteristics of the prairie streams, which have their beds in the drift, rapids, if there are any, occurring over accumulations of bowlders; but east of the limit of the drift are met the rock-bed and banks and the deep valleys previously described. The Cannon river lies a little north and west of the driftless region, as marked upon the maps, but nevertheless reaches the solid rock before it has passed over more than a third of its course.

Flow.—The five rivers considered do not have the natural reservoirs to draw from in low water which characterize the streams draining northern Wisconsin and Minnesota. No lakes and tamarack swamps store the rains and deal them out gradually during the dry months, and there are no unbroken forests to check evaporation. But they do not belong at the other extreme of the series presented by the upper Mississippi basin, and if they cannot be classed with the Leech lake region and its neighbors, no more can they be fairly classed with the prairie drainage at the headwaters of the Minnesota. Their position is midway between the two. There is more or less timber-land along the valleys and in groves, and numerous springs trickle out along the sides of the bluffs. A large number of these springs is due to a layer of impervious shale in the midst of the Trenton, and where that comes out along the face of the bluff a line of springs is often noticed. (*a*)

The great number of lakes found in Minnesota is due to the depressions and basins left by the glaciers—basins which have not yet been filled up or drained by erosion. These do not exist in a country unmodified by glacial action, and hence the very few lakes found in the region or at the sources of the rivers where they rise in the drift country. The Cannon river may be considered the only one fed by lakes, and has several of shallow depth in the upper part of its course.

The Big Woods, which cross the basin of the Minnesota below the great bend to the northeast, send their outposts into the region drained by the Cannon. So far as can be ascertained, the five rivers owe what reputation they have for regularity of flow mainly to the many springs which feed them. "Bluffy streams", they are called by the millers. No gaugings of their discharge are available—merely the estimates of millers as to the power ordinarily obtainable from them; and while that is of practical value in estimating their capacity for manufacturing, it is a very rough way of determining the actual flow. However, after comparing with other streams, and with these millers' estimates, from 0.28 to 0.38 cubic foot per second per square mile was fixed upon in the tables for the average ordinary low flow, and 26 to 28 per cent. of the annual rainfall for the average yearly flow, the average annual precipitation varying from 20 to 32 inches. The true amount may be considerably greater or smaller than this, but that is the conclusion reached after a consideration of the circumstances of the case.

Fall.—The country west of the Mississippi in southern Minnesota and northern Iowa is at a high altitude, and the sources of the principal streams are at a height varying from 1,100 to 1,400 feet above the sea. To reach the Mississippi at an altitude of about 625 feet above sea-level, they have to descend from 500 to 700 or 800 feet; and as this fall takes place within distances varying from 80 to 100 miles, it is apparent that a rapid descent is to be found in them. A part of this is often concentrated in rapids and falls in the limestone sections.

The bluffs along the Mississippi and the lower parts of its tributaries are from 400 to 500 feet or more in height, and the descent in the streams is due, not to a rapid slope in the general surface of the country, but to the fall in the valleys which they have eroded. A good idea of the profile of the country in an east-and-west direction is given by the levels of the Minnesota Southern railroad, which passes up the Root River valley for 43 miles to Whalen, and then continues west.

Starting from the Mississippi, in which the low-water elevation is about 625 feet above the sea, the railroad rises to an altitude of 786 feet at Whalen; then at Fountain, 59 miles from the Mississippi, it is 1,302 feet above the sea, having risen 400 feet in the last 6 miles while ascending from the valley; then it runs along for some 25 miles at varying elevations, finally reaching the summit level, 90 miles from the Mississippi, at an elevation of 1,412 feet above the sea, and then descending to the Cedar river.

CANNON RIVER.

The Cannon rises about 25 miles north of the southern boundary of Minnesota, and after a course of 90 miles (map measurement) enters the Mississippi 21 miles below the mouth of the Saint Croix river. Its general course is a regular curve, convex toward the northwest. Nominally, the Cannon rises in the western part of the basin, and the stream, 43 miles long, which flows from the south, is called the Straight river, uniting with the Cannon at Faribault. Practically the Straight river is a continuation of the Cannon. It was called by the Indians Owatonna, meaning straight; and it is thought that this name must have been given in a spirit of irony, as it is a very crooked stream.

The Cannon, as previously mentioned, rises in the drift and flows through it, but has cut down to the rock below, forming rapids with solid banks and bed, and offering good water-powers.

The Straight river first succeeds in cutting through the drift and reaching the bed-rock just below the town of Owatonna, about half-way between its source and Faribault. There it strikes the Trenton limestone, and thence down to the Mississippi the river runs below the level of rock outcrop.

a See *Geological Report of Minnesota for* 1876.

In crossing Rice county, from south to north (Faribault is situated in the southern half of the county), the river completes its excavation through the Trenton formation, cuts through the Saint Peter sandstone, and penetrates 30 feet into the Lower Magnesian limestone, descending about 150 feet in a distance of some 20 miles. Then it continues through the Lower Magnesian strata, and comes out upon the Potsdam sandstone. Above Owatonna the Straight river is not so rapid, and has no improved powers. Below Owatonna there are several powers, and, besides the number of improved sites, there are a number of available ones which yet remain to be developed. From a few miles below Cannon River falls, which are about 20 miles above the mouth of the river, down to the Mississippi the bed and banks are of earth, and more or less flowage would be caused by dams. The town of Cannon River Falls probably marks the locality where the river leaves the Lower Magnesian limestone and enters upon the softer sandstone below. As a general rule the bed and banks of the river consist of gravel or clay, but at places a solid rock bed is found.

The lakes feeding the Cannon drain into it before the junction with the Straight river at Faribault, and serve to make it more steady in flow than the latter stream. There is some idea among the mill-owners of establishing a system of reservoirs out of these lakes and still further regulating the discharge. They claim that according to survey 587,000,000 cubic feet could be stored by raising the level of the lakes 2 feet. This would give a discharge of about 75 cubic feet per second for three months. The Straight river has few lakes, and diminishes in winter and dry seasons so that three out of the five mills upon it have steam-power as an auxiliary to their wheels.

At Faribault, where the two streams unite, it is not considered advisable to build more than a six-run mill, with a head of 10 feet, although during part of the year many more runs could be operated; but during a severe winter there might not be sufficient water to run them at all. Using the estimate for ordinary low flow given in the tables, with the understanding that it does not apply to the winter months, gives a discharge at the mouth of 433 cubic feet per second, furnishing, under a head of 10 feet, 491 theoretical horse-power.

Utilized powers.—Starting with the Cannon above the junction with the Straight river, the first power from the source is at Waterville, where there was once a mill with four runs, under a head of 5 feet. It was burnt down, and the power is unused. Below is Morristown, where there is a custom mill, with 7 feet head of water. One mile below is a locality unimproved, where, by cutting across a neck of land, a head of 12 feet can be obtained. Next is the Warsaw dam, giving a head of 4.5 feet, which could be increased to 6 feet, but there is no mill there now. Then comes the Polar Star flouring-mill, at Faribault, with a head of 9.5 feet, and a capacity of from 200 to 300 barrels of flour per day. Steam is used part of the time.

The mills on Straight river are these, from the source to Faribault:

Owatonna mill, 5.5 feet head; Clinton mill, 8 feet head; Walcott mill, 10 feet head; "Straight River stone mill," 9 feet head; the Green and Gold mill, 8 feet head. The three upper ones each use 40 horse-power, and the remaining two use 60 horse-power each. All but the upper two use steam also. There are a number of unimproved powers, offering a head of from 7 to 13 feet, which can be made available.

Below the junction of the Straight and Cannon, at Faribault, there are the following powers:

Scotte's mill is 3 miles below Faribault, and has a head of 8.5 feet. Above it are two unimproved locations where a head of 9 feet is obtainable.

About 1.5 mile below Scotte's mill is an unimproved power with a head of 7 feet, and about 2 miles beyond is another of 9 feet. The next mill is at Dundas, where there is a head of 9 feet, and a daily product of 185 barrels of flour; then the Northfield mill, with a head of 10.5 feet, and a capacity of 300 barrels per day.

Below this there are four mills with heads ranging from 7 to 13 feet.

The power at Cannon falls is fine, but unimproved; a head of at least 20 feet is available. There is unimproved power both above and below, but for the lower half of the distance down to the mouth there is little, if any, available power.

The census returns show that several of the mills have steam-engines for use during low water. According to the returns there is a total of 1,220 horse-power in use on the Cannon and Straight rivers, all being used by flouring- or grist-mills, with the exception of 6 horse-power, taken by a small machine-shop.

There are several small tributaries of the Cannon, as Little Cannon river and Belle creek, which have one or two small mills upon each. Some brooks fed by springs furnish small mills with very reliable power. Spring brook, for example, enters near the mouth, and supplies four or five such mills.

ZUMBRO RIVER.

This stream enters the Mississippi 7 miles below the mouth of the Chippewa, after a general easterly course through a basin 1,346 square miles in extent. The length, as measured on the map, to the farthest source, is about 80 miles. Some 40 miles from the mouth the river divides, the North branch flowing from the west, and the South branch from the south. About 8 miles south of the junction the South branch receives the Middle branch, which flows directly east. Near its head the South branch radiates into a number of small streams.

About two-thirds of the entire Zumbro basin is tributary to the river above the junction of the North and South branches. From the junction down to the mouth the basin is not more than 10 or 15 miles wide, and the side streams are small in size. Of the three branches the South and the Middle branches drain about equal areas, much larger than that tributary to the North branch.

The lower part of the river is in the driftless region, but the sources are in a country covered with drift. This, however, has not prevented the stream from cutting down to the rock; and all the branches, especially the South branch, soon strike the bed-rock. This occasions many available water-powers in the upper part of the basin, where the bed and banks are largely rock, giving good locations for dams. In the lower portion of the river the bed is mainly of gravel, and generally one bank is low, making the development of water-powers expensive. The valleys and bluffs characteristic of the region are found along the Zumbro and its tributaries.

There is a moderate amount of woodland in the Zumbro basin, but there are very few lakes, and the flow would be extremely unsteady were it not for the many springs which feed the streams. These come out of the bluffs, along the Trenton limestone, as previously described, and serve to some extent to maintain the low-water flow of the river. Nevertheless, it is not remarkable as a steady stream, and in severe winters the discharge is very much diminished. A few of the mills upon it have steam-engines to assist their water-wheels.

The following statement regarding the Middle branch is quoted from the *Geological Report of Minnesota* for 1876: "For three or four months in the winter of 1874–'75 the mills had no water. Some years, however, they continue to have water the year through. The water in the North branch is even more unreliable than this."

There is considerable fall in the river. The surface of the water in the Middle branch at Orinoco, 4 or 5 miles above its mouth, is 935 feet above the sea, and hence the total fall to the Mississippi is about 300 feet, or nearly 6 feet per mile. While there are some 15 or 18 improved powers upon the main river and its branches there are also several undeveloped sites, and these are mainly upon the branches. The main stream is expensive to improve, and has only one mill upon it according to the census returns.

Utilized powers.—The census returns credit the Zumbro and its three branches with a total of 707 utilized horse-power; all but 15 horse-power, used by a saw-mill, is taken by flouring- and grist-mills, working under heads varying from 7 to 17 feet, with the exception of the Mazeppa mill near the mouth, with a fall of 28 feet, which gives 105 horse-power, the others averaging from 20 to 30 horse-power under a head of about 11 feet. Three of the smaller-sized mills have steam-engines. Most of the mills are upon the Middle branch, which divides into two forks a few miles above its mouth. Upon the South branch there are only two mills. The mill at Rochester, on the South branch below the junction of its radiating branches, has four runs of stones under a head of 16 feet, requiring 65 horse-power. Steam is used, but the water-power is sufficient for four runs during nine months of the year, and during half the year many more runs could be operated. The other mill is three quarters of a mile below, and uses 100 horse-power under a head of 12 or 14 feet; no steam is used, but Bear creek enters above the mill and adds considerably to the power.

At Orinoco, on the Middle branch, there is a fine power with a head of 15 feet, which has been partly utilized by a feed-mill. The intention was to erect a flouring-mill of four and eventually of eight runs of stones. The existing mills on the Middle branch are mostly small, the largest using 75 horse-power under a head of 17 feet. The mill on the main river is at Zumbro falls, a few miles below the junction of the North and South branches, and is only a small mill of about three runs, under a head of 8 feet.

ROOT RIVER.

The basin of the Root river, 1,669 square miles in extent, is elliptical in general form, with the major axis extending east and west, and along this axis the river's course is located for about 45 miles, to where it divides, the South branch flowing from south of west and the North branch from north of west. About 20 miles above this junction the Middle branch flows into the North branch from the west. About half the entire basin is tributary to the river above the junction, and of this area the North and Middle branches together drain considerably more than the South branch.

The sources are in the drift, but the greater part of the basin lies within the driftless area, and some of the most striking scenery of the entire region is found along this stream. The different branches very soon penetrate to the rock, and before they unite have cut through the Magnesian limestone, reaching the equivalent of the Potsdam sandstone just above the junction.

Like the Zumbro, the Root owes what regularity of flow it possesses to the numerous bluff springs, and, so far as can be gathered from the opinions of millers, it is more steady than the former, maintaining its flow fairly well during summer and winter. None of the mills upon it use steam-power to assist their wheels in low stages. According to the statements of an experienced miller familiar with the stream, the ordinary capacity of each of the three branches is about 65 horse-power under a head of 10 feet. Where seen they each averaged about 50 feet wide, while the main river is from 200 to 300 feet in width. The bed of the river and its branches is largely rock, and one bank at least is usually high and firm.

There is a large fall in the Root river; the total descent from the extreme sources cannot be much less than 750 feet, or about 8 feet per mile. The greater part of this descent is concentrated in the branches, as the total fall below the junction is only about 161 feet, or 3.5 feet per mile.

Utilized power.—The Root river stands first in the list in point of developed water-power, and is not exceeded by any stream of its size in Minnesota or in Wisconsin. The census returns show that 1,344 horse-power is in use upon it, and of this all is taken by flouring- and grist-mills, with the exception of 27 horse-power used by a saw-mill, 5 horse-power by a blacksmith-shop, and the power used by two small woolen-mills. Many of the flouring-mills are extensive, having a daily capacity ranging from 200 to 400 barrels, and using from 100 to 200 horse-power. The head of water used varies from 6 to 12 feet, with the exception of one head of 22 feet. The largest mills are on the main stream, and there are eight of them, situated at the Junction, Whalen, Rushford, Houston, and Hokah.

On the South branch there are four flouring-mills, ranging from 50 to 175 barrels in capacity each, and a small woolen factory. On the Middle branch and its forks are five mills, all of small size, as the largest has a capacity of only about 75 barrels. On the North branch are four flouring-mills and a woolen factory. The largest mill is 2 miles below Chatfield, and has an average capacity of 150 barrels, under 15 feet head of water.

There are many fine water-power sites yet undeveloped; four or five occur in the 20 miles from the mouth of the Middle branch to the mouth of the South branch.

On the Middle branch are the Tunnel mills, where, by a tunnel through a rocky neck of land, a head of 30 feet is made available, and several localities are mentioned in the geological reports, where by similar tunnels even greater falls can be obtained. On the main river the fine sites are mostly developed. There is one valuable one affording a head of 12 feet at Peterson, 6 or 8 miles below the junction. The mill which formerly stood there was burnt down.

Many of the minor tributaries of the Root river have small mills upon them, and are very valuable for supplying the local demand for grinding. Some of these mills do merchant work as well.

UPPER IOWA RIVER.

This is the smallest of all the five rivers situated in the region under consideration, and drains 952 square miles, of which 180 square miles lie in Minnesota and the remainder in Iowa.

The river rises in Mower county, Minnesota, south of the sources of the Root river, flows southeast to Decorah, in Iowa, about 15 miles south of the state line, and then runs northeast to the Mississippi, meeting it about 3 miles below the line. It does not divide into several different branches, like the Root and Zumbro, but its tributaries are small brooks. The country through which it flows resembles the basin of the Root river to a great extent. It rises in the drift and cuts down through the successive strata to the Potsdam sandstone, leaving the Trenton a few miles below Decorah. The total descent cannot be far from that of the Root river, but it is not considered so rapid a stream. Like the rivers last discussed, its flow is largely maintained by springs.

There is only one mill in the first 20 or 25 miles from the mouth, and that uses only 25 horse-power, under a head of 6 feet. All the water-power used is on the upper part of the river. According to the census returns the total is 659 horse-power, but that does not include a small woolen factory at Decorah nor a paper-mill a few miles below. Nearly all the power is used by flouring-mills. The largest takes 150 horse-power, under a head of 11 feet, and the average is about 50 horse-power, under 9 feet head of water. The large mill is situated at Decorah.

The upper Iowa river is credited with a total of thirteen flouring- and grist-mills, of which two are situated in Minnesota. There is also a wagon factory using 20 horse-power. The side streams furnish a number of powers for small mills.

TURKEY RIVER.

The Turkey river rises about 6 miles south of the southern boundary of Minnesota, and south of the sources of the upper Iowa, and flows southeast 115 miles, by map measurement, to the Mississippi. The mouth is about half way between the mouth of the Wisconsin and the northern limit of the state of Illinois. The basin is 90 miles long, averaging 18 or 20 miles wide.

A stream about 50 miles long, called Volga river, enters from the west 20 miles from the mouth; and about 75 miles from the mouth Crane creek is received from the west. Crane creek is 50 miles long, and drains about the same amount of territory that the main river does above the junction.

The country drained by the Turkey river is similar in many respects to that through which the Root and upper Iowa rivers run. The valley of the lower river is deep and bounded by abrupt bluffs, but these decrease in size as one ascends the stream, until this is found running through the undulating prairie region, in which the timber is mainly confined to the water-courses, and where these have not succeeded in cutting far into the drift which forms the surface. In the lower part of the basin there are groves and some extensive bodies of timber.

The course of the river is parallel with the strike of the rock strata, and except at the sources it flows over the Galena limestone, a division of the Trenton, cutting through into the Trenton proper from a few miles above Crane creek down to the mouth of the Volga river. (*a*) This limestone, where not covered by drift, etc., forms excellent bed and banks for the erection of dams.

There are many springs feeding the river, and it is considered a rather steady stream.

At Elkader, 14 miles above the mouth of the Volga, where high rocky banks restrain the channel to what is not over the average width, the ordinary rise is from 4 to 6 feet, and during the extraordinary freshet of June, 1880, the waters rose only 12 feet. The available power at that place under a head of 10 feet is considered by the millers to be 225 or 250 horse-power at the lowest stage, and this agrees fairly with the estimate given in the tables, on the basis of 0.28 cubic foot per second per square mile for the ordinary low flow. According to the tables the power at the mouth, with the ordinary low flow under a head of 10 feet, is 548 theoretical horse-power.

The mouth of the river is 593 feet above sea-level, and judging from the altitude of the sources of the Root and the upper Iowa the source is probably 1,000 or 1,200 feet above the sea. This would make the total fall from 400 to 600 feet, or from 3.5 to 5 feet per mile.

A large part of the water-power of the basin is on the Volga river and Crane creek, and several mills are situated on each stream.

Utilized powers.—According to the census returns there is 906 horse-power in use on the Volga river, two saw-mills taking, respectively, 20 and 40 horse-power, and eighteen flouring- and grist-mills utilizing the remainder. Of these all but the Elkader mill are on the portion of the river above Clermont, which is about 10 miles below the mouth of Crane creek. Information was obtained of Thomson's mill below Elkader, a four-run mill under a head of 12 feet, which apparently is not mentioned in the census statistics. The mills are not very large; only three exceeding 60 horse-power, and these take 150, 90, and 80 horse-power, under heads of 12, 8, and 9 feet, respectively. The average is perhaps 45 horse-power under a head of about 8 feet.

There are six flouring- and two saw-mills on the Volga, using a total of 287 horse-power, the largest taking 64 horse-power under a head of 9.5 feet.

On Crane creek there are four flouring-mills, using a total of 118 horse-power. There are other tributaries of the Turkey river, as Otter and Elk creeks, which have a limited number of mills upon each.

ARTESIAN WELL WATER-POWER AT PRAIRIE DU CHIEN, WISCONSIN.

Prairie du Chien is a city of about 2,800 inhabitants, situated on the east bank of the Mississippi, about 3 miles above the mouth of the Wisconsin river. Between the river and the highland is a wide bottom, through which passes a slough filled with back-water when the river is high. From this slough rises a slope 30 or 40 feet in height, and then a wide terrace leads to the main bluffs of the Mississippi valley. On this terrace and slope the city is situated. A large 8-inch artesian well supplies the town with an abundance of water, which is carried through a system of street hydrants, and runs in profusion down the gutters of the main street. There are six wells in different parts of the place, and two of them are employed for hydraulic purposes.

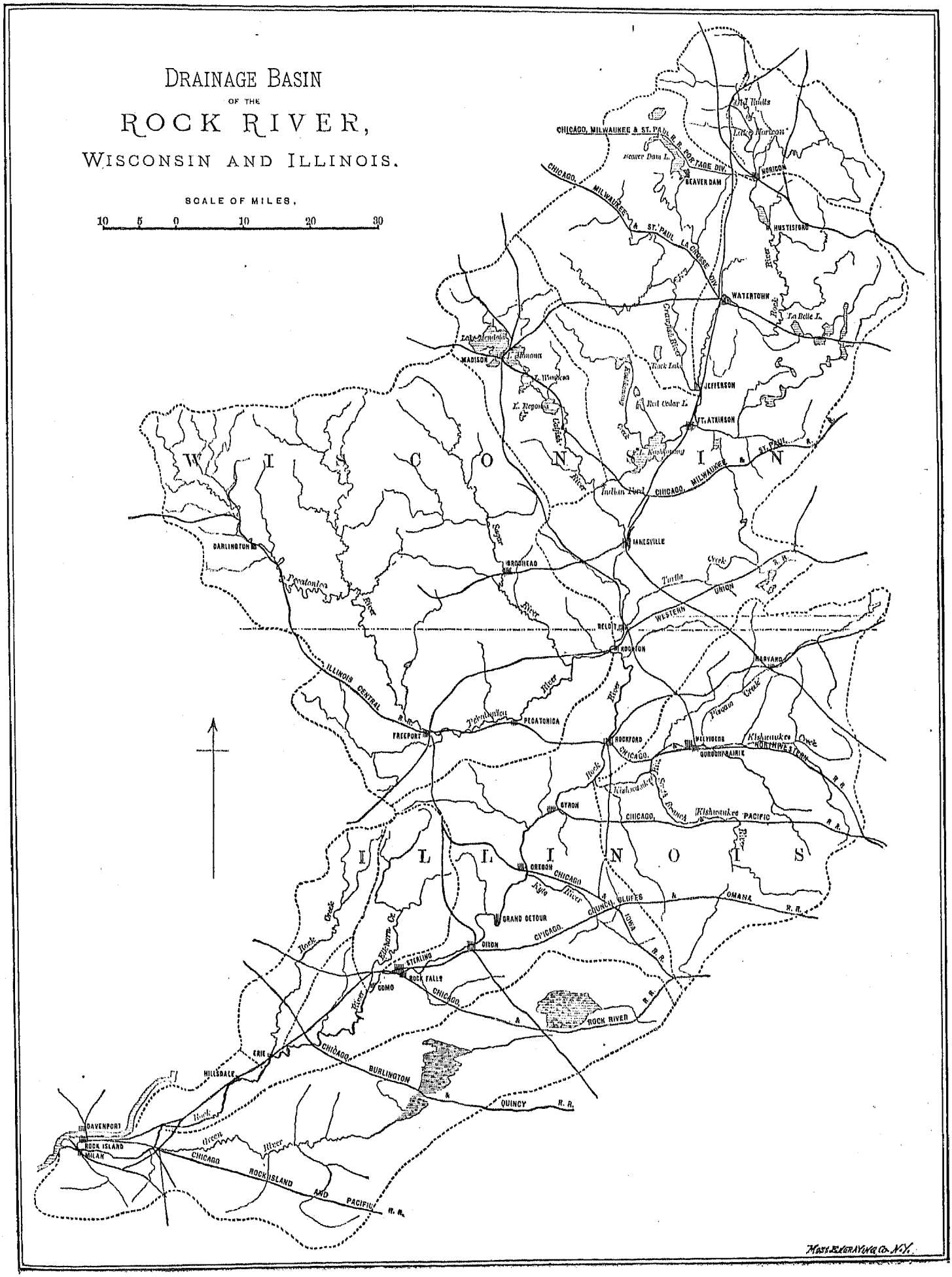
Prairie du Chien is so situated that the rock strata mentioned in the last few pages have a south and southwest dip toward it, owing to the inclination of the Archæan base which underlies them. This is of course impervious to water, while the sandstones and some layers of the limestone above are easily penetrated. The lower member of the sedimentary series, the Potsdam sandstone or its equivalent, is underlaid by the granitic rock, and above it are the limestone and impervious shales of the Lower Magnesian. This sandstone has a broad surface exposed in Wisconsin and in Minnesota, and becomes charged with water, and it is to this water taken from the country northward that Prairie du Chien owes its artesian wells. They are not confined to this one locality; west in Iowa and east and northeast are many others.

There are two levels at Prairie du Chien at which water is struck, one at a depth of 1,000 feet and one some distance above, but the deep-seated wells appear to be the best. The opening of a new well very slightly diminishes the flow from the others. The deep wells are heavily charged with mineral salts, chiefly common salt and bisulphate of lime, which rust iron pipes.

The two wells used for water-power are very near the foot of the slope leading from the bottom-land to the terrace, and are owned by Mr. H. Weniger, the proprietor of the grist-mill which uses their power. The wells are about 50 feet apart, and have these dimensions: 5§-inch well, 1,012 feet deep; 8-inch well, 1,044 feet deep. After passing 118 feet of sand, and then 120 feet of shale, as the proprietor called it, water was struck, which increased in flow with the depth bored. The expense of the 8-inch well was $3 per foot, and of the other $2 per foot, making a total of $5,150. The mill is a small one of only two runs, using about 9 horse-power, only one run being operated at a time.

The method of taking the power is by transmitting the pressure of the two flowing wells directly to the wheel. Two iron pipes unite in a drum, 3 feet in diameter and 3 feet long, with its axis vertical, placed about 10 feet below

a Geological map of Iowa.


DRAINAGE BASIN
OF THE
ROCK RIVER,
WISCONSIN AND ILLINOIS.
SCALE OF MILES.
10 5 0 10 20 30
WISCONSIN
ILLINOIS
CHICAGO, MILWAUKEE & ST. PAUL R.R. PORTAGE DIV.
CHICAGO, MILWAUKEE & ST. PAUL LA CROSSE DIV.
Beaver Dam L.
BEAVER DAM
HORICON
HUSTISFORD
WATERTOWN
Rock River
La Belle L.
Lake Mendota
MADISON
L. Monona
L. Wingra
L. Koshkonong
Rock Lake
JEFFERSON
Red Cedar L.
FT. ATKINSON
Crawfish River
Catfish Creek
Indian Ford
CHICAGO, MILWAUKEE & ST. PAUL R.R.
JANESVILLE
BARLINGTON
Sugar River
BRODHEAD
Pecatonica River
Turtle Creek
UNION
WESTERN
BELOIT
ROCKTON
HARVARD
ILLINOIS CENTRAL R.R.
Pecatonica River
PEGATONICA
FREEPORT
ROCKFORD
CHICAGO
Pecatonica River
Pecatonica River
Kishwaukee River
Kishwaukee Creek
WELVIDERE
GURDON
NORTHWESTERN R.R.
Kishwaukee River
South Branch
BYRON
CHICAGO, Kishwaukee PACIFIC R.R.
OREGON
CHICAGO & GALENA R.R.
Rock River
GRAND DETOUR
CHICAGO & CHICAGO, CLIFFS & IOWA R.R.
OMAHA R.R.
Rock Creek
Elkhorn Creek
DIXON
STERLING
ROCK FALLS
COMO
CHICAGO & ROCK RIVER R.R.
Rock River
ERIE
CHICAGO, BURLINGTON & QUINCY R.R.
HILLSDALE
DAVENPORT
ROCK ISLAND
MILAN
Rock River
Green River
CHICAGO, ROCK ISLAND AND PACIFIC R.R.

the earth surface at the wells, and 30 or 40 feet from each. In this drum is the wheel, 8 inches in diameter, with 120 inches of opening, manufactured in Dubuque, Iowa. It was the intention of the proprietor to erect a stand-pipe 35 feet high, and have the pressure of the column of water upon the wheel, but this would not increase the power obtainable over what is obtained from the direct pressure of the wells, except as it might increase the efficiency of the application. The height of the water in the stand-pipe would vary as the velocity of efflux from the well varied, and would equal the hydrostatic head less the head due to this velocity of efflux. In the same way, by transmitting the pressure directly from the well, as at present, this pressure is that due to the hydrostatic head less the head due to the velocity of efflux from the well. By diminishing the flow from the wheel the pressure can be increased until the hydrostatic head is reached, when the flow would be zero. By increasing the wheel-opening until it took all the flow which would come from the wells at the level of the wheel, the pressure of water would be diminished to that which would obtain if the wells were flowing freely at that level. The actual flow of the wells is not known, nor is the *hydraulic* head under the present method of using the water. The *hydrostatic* head is said to be 65 feet. Without knowing the hydraulic head or the velocity of efflux it is impossible to calculate the flow, but an approximation is possible in this way:

There is a 5⅝-inch well, whose mouth is 28 feet higher, and which has an intimate connection with the two wells under consideration. Its flow is 116,125 cubic feet per day, or 1.344 cubic foot per second, and this gives a rough means of estimating the discharge required. Assuming that the velocity of efflux at the lower level is that at the higher level, plus that due to a head of 28 feet, gives a discharge from a 5⅝-inch pipe of 7.443 cubic feet per second, and from an 8-inch pipe of 15.036 cubic feet per second. Hence, not allowing for friction, etc., the total natural flow from the two wells, according to this calculation, is 22.48 cubic feet per second. This, with the head of 28.9 feet, would give a total theoretical power of 74 horse-power.

There is gas in the water, but this acts merely to transmit the pressure, as the drum is air-tight. The flow is very steady throughout the year. The water passes from the wheel into the slough in the flat. In the high flood of June, 1880, the back-water from the Mississippi rose 16 feet over the wheel, but it only slightly diminished the power obtained.

ROCK RIVER.

General remarks.—The name of this river, translated into the language of the Indians, is Sinnissippi, and by this name it was known to the aborigines.

It rises in the tract of land lying between the sources of the upper Fox and the southern end of lake Winnebago, in Wisconsin, and enters the Mississippi at the foot of Rock Island rapids. Its general course is southwest and approximates to the arc of a circle, convex to the southeast, with a chord of 180 miles and a versed sine of about 30 miles. The total length of the river is 286 miles, of which distance nearly half is in Wisconsin, and the rest in Illinois. The source is in an extensive swampy region.

In 1842 a dam was built at Horicon village, forming a lake in this region, covering about 50 square miles, called lake Horicon, and lying south-southwest of lake Winnebago. In 1868 the dam was removed, on account of land damages, and the place has reverted to pretty much its original condition. Many maps yet exist with the shore-lines of lake Horicon marked upon them.

The drainage basin, of 10,973 square miles area, has 5,653 square miles situated in Wisconsin and 5,320 square miles in Illinois. It may be roughly described as pear-shaped in form, with the stem at Rock Island. The length is 175 miles. The greatest width is near the state line, where for 20 miles or more it averages about 80 miles; above that it averages 40 or 50 miles, while below, in Illinois, it soon narrows to 40 miles, and then to 25 miles.

In Wisconsin the river runs rather in the eastern side of its basin, but near the state line it approaches the center, which it follows for a distance through Illinois, finally flowing decidedly near the western boundary line of its drainage area. This basin of the Rock river is an undulating semi-prairie region. Large expanses of unbroken prairie, groves, and some more extensive bodies of timber, swamp, and lake, are all to be found within its limits. The soil, from southern Wisconsin down, makes very fine farming land, and has been cultivated from an early day.

The population of the basin in 1870 was 470,932, and in 1880 had increased to 485,578—a population, according to the census statistics, of 49.5 per square mile.

A large number of railroads intersect each other within the limits of the basin, and below the boundary between Illinois and Wisconsin there are nine independent crossings of the river by different lines of railroad, while in Wisconsin there are five more. The total number of places at which railroads cross the river is about twenty. Although this number might not be considered remarkable in some sections of the country, it shows a state of general industry more advanced than in the basins of the Wisconsin, Chippewa, etc.

Distribution of powers.—At a large number of the railroad crossings of the river are flourishing towns and cities, doing a good trade with the farmers of the surrounding region, and contributing more or less to the manufactures of the country, while some, as Rockford, for example, are conspicuous among the manufacturing centers of Illinois. This manufacturing industry of the Rock River basin is due to the water-power which the river affords all the way along its course, from the small stream emerging from the Horicon swamp almost down to its very mouth.

There are eighteen points at which the power of the river is in use, eight of them in Illinois, and at thirteen of these places are cities, towns, and villages, with a total population of 50,500. The following table gives the population of the manufacturing places using water-power, from the source down:

WISCONSIN.			ILLINOIS.		
Place.	Distance from source of river.	Population in 1880.	Place.	Distance from source of river.	Population in 1880.
	Miles.			*Miles.*	
Hustisford	35	488	Rockton	135	940
Watertown	62	7,883	Rockford	153	13,129
Jefferson	80	2,115	Oregon	170	1,088
Janesville	115	9,018	Dixon	202	3,658
Beloit	131	4,790	Sterling	215	5,087
			Rock Falls	215	804
			Lyndon	234	557
			Milan	284	845

The chief points of developed water-power in Illinois are Rockford, Sterling, and Rock Falls; and in Wisconsin, Janesville, Beloit, and Watertown.

The census statistics show a total utilization of water-power on the river of somewhat more than 7,230 horse-power, by 130 separate establishments, of which 83 are in Illinois and 47 in Wisconsin. In Wisconsin over half the establishments are flouring-and grist-mills, while in Illinois there is more general manufacturing, the natural outgrowth of the requirements of a more numerous population.

Business.	NUMBER OF ESTABLISHMENTS.	
	Wisconsin.	Illinois.
Flouring- and grist-mills	26	21
Saw-mills	1	1
Paper-mills	2	7
Agricultural implements	2	14
Machine-shops and foundries	2	14
Woolen-mills	4	1

The remaining establishments are devoted to various other industries.

The existence of only two saw-mills on the river, and those small ones, shows that lumbering is a business foreign to this drainage basin. The southern limit of the pine belt is many miles north of the sources of the Rock, and these mills are probably used to satisfy a local demand for hardwood lumber.

Geology.—The Rock River basin may be said to belong to a different geological horizon from all the rivers north of it in Wisconsin. Although most of the surface is entirely covered with a great blanket of drift, as is more or less the case with the other streams, yet it is noticed, that the Rock river does not rise in the old Archæan region or on the Potsdam sandstone, but its sources are determined by the great overlying ledge of Lower Magnesian limestone, which, presenting its steep front to the north, turns the waters of the Wisconsin river west.

From this shelf the river flows southwest, following approximately the line of strike of the rock strata; hence, perhaps, its gradual westward curve, and its running through almost its entire course in the region of outcrop of the Trenton limestones.

Continuation of Green Bay valley.—The Green Bay valley, along which the lower Fox river flows, has been mentioned in describing that river. It runs southwest along the Trenton limestone, with a gradual slope westward, and on the east a steep bluff formed of soft Cincinnati shales, with hard overlying Niagara limestone.

Reaching the summit at the head of lake Winnebago, this valley continues straight on in a southwest direction, with its abrupt eastern ridge unchanged, and forms the valley of the Rock river, until the ridge gradually sinks beneath the thick accumulation of drift, and finally disappears in the southern tier of counties of Wisconsin. The opinion expressed in the *Geological Report of Wisconsin*, from which these facts are mainly gleaned, is that while the valleys of the two rivers existed previous to the Glacial age, yet they were deepened, especially the Green Bay valley, by a glacier, which ground its way through the basin of lake Winnebago, and over into the Rock valley, where it spread out to the west.

As the tendency of the lake Winnebago drainage in flowing northeast is to run close to the eastern barrier of the valley, so is it with the Rock river in flowing southwest. The dip of the strata, where not prevented by the drift, crowds the channel of drainage against the ridge.

The course of the river above Watertown is comparatively near the eastern limit of the valley, but about 10 miles above Watertown accumulations of drift have turned it from south to northwest, and finally southwest again, away from the eastern line of water-shed. The channel of the river is partly in the drift and partly in the rock, where it has succeeded in cutting through the former.

Lake Horicon, which existed until 1868, although a body of water formed by an artificial dam, yet occupied the site of an ancient lake, caused by the body of drift, which formed a natural barrier to the passage of the water. Gradually this was eroded and the lake drained, probably by the same passage which now forms the channel of the river past the village of Horicon. A dam near there, 200 feet long, would raise the water 10 feet, and restore the old lake to a certain extent.

Effect of the rock strata on the powers.—A few miles above Fort Atkinson, which is about 85 miles from the source, the river leaves the Trenton, and runs in the Saint Peter sandstone down to the state line, where it again passes upon the Trenton limestone. The result is important in its bearing upon the water-powers. The power at Watertown has fine limestone bed and banks; the powers below, in the sandstone section, so far as was ascertained, have gravel as a foundation for dams, and more or less trouble has been experienced from their instability; in Illinois hard rock is again met, and a superior bedding for dams. In places, however, the limestone is covered with drift and loose material.

There appears to have been some disturbance of the rock strata in northern Illinois, elevating them so that there is an isolated section of the Rock river, from some distance above Oregon to Grand Detour, a space of about 15 miles, in which the river runs in the Saint Peter sandstone, striking the Trenton formation again near Dixon. At that place limestone forms the left bank, but slopes so rapidly below the gravel-bed of the river as to be of no service in the construction of the dam.

In the lower section of the river the Niagara limestone appears in the bluffs along the valley, and this must form the limestone bed over which the river flows near its mouth, for the *Illinois State Geological Report* represents it as emptying into the Mississippi from the overlying Hamilton group. The extensive series of the sub Carboniferous appears to be entirely wanting in the valley, as the coal measures rest upon the Hamilton, and finally disappear from the Niagara. It is to these coal measures that the seam of coal, and soft, ferruginous sandstone found on the river at Milan and above are probably due.

It will be seen from the short account given that the course of the river is practically over the limestone strata, and to this fact is due one of its important features. Unlike the Wisconsin, Chippewa, Black, etc., which flow over geological regions of widely different character, the Rock river runs on a base of comparatively uniform hardness. There is an Archæan section of hard crystalline rock furnishing fine water-power, and then a region near the mouth where the bed is over the soft sandstone, which wears down to a uniform slope and affords few, if any, sites for water-power; but from source to mouth there are rapids either directly upon the hard limestone, or due more or less remotely to it, and many available sites, the last one within 2.5 miles of the Mississippi.

The western extension of the Rock River basin in Wisconsin, drained by the upper waters of its tributary, the Pecatonica, lies within the limits of the driftless area, described on a previous page, and the valleys occupied by the streams are not filled with drift, as is so characteristic of the rest of the basin.

Fall of the river.—The sources of the Rock river are about 876 feet, and the mouth is 536 feet, above sea-level, making the total descent about 340 feet. The average slope is 1.2 foot per mile. The most rapid section is in Wisconsin, from the mouth of the Catfish down to the Pecatonica river, where for 30 miles the average slope is 1.9 foot per mile, and next, from Oregon to Sterling and Rock falls, in which distance of 36 miles the average slope is 1.31 foot per mile. Locally there are more rapid descents than these.

The figures show that there is a rather uniform distribution of the descent, as mentioned in treating of the rock strata, and the variations serve to give a wave-like form to the profile, which is otherwise a curve, slightly concave downward. It is mainly at the local concentrations of the descent that the inviting water-powers are situated, and consequently that the prominent river towns are located.

Of the 340 feet of total descent, 126 feet is improved and in actual use, leaving 214 feet undeveloped. Mr. Joseph P. Frizell allows one-ninth of the descent of a fully improved river for providing the movement of the water, and using this estimate there are about 204 feet of unutilized fall *theoretically* available. A large amount of this is practically available—how much, would require an extensive survey to determine—but there are several fine sites lying idle which capitalists have had under consideration. These will be mentioned when the local descriptions are given.

Flow of the river.—There has been no regular series of measurements made of the discharge of the Rock river, and hence any estimate of the average or low flow must be more or less approximate. The most reliable data at hand are the result of a survey at Milan, near the mouth, and by a careful gauging the low-water flow was determined to be 3,932 cubic feet per second.

In the tables giving the flow of the tributaries of the Mississippi, the ordinary low flow of the Rock is taken to be 3,900 cubic feet per second, and the average yearly flow 9,944 cubic feet per second. These amounts agree well in the comparison with the other streams. The average yearly flow is 35 per cent. of the annual precipitation, and the ordinary low flow is about 0.36 cubic foot per second per square mile.

It will be noticed that the flow according to these estimates is nearly as great, relatively to the areas drained, as in the case of the "high-flow" rivers of Wisconsin. At first thought this would seem impossible, for the extensive tamarack and cedar swamps of northern Wisconsin are wanting in the basin of the Rock, and the surface is not so generally wooded as is the case farther north; but taking the average for the basin, the annual rainfall is from 2 to 5 inches greater, and there is altogether a large amount of woodland, while swamps are by no means rare. The region of old lake Horicon is very swampy, and the tract drained by the Green river abounds in low, swampy ground.

There are some ten lakes represented on the maps as tributary to the Rock river. These are in Wisconsin, and have a total area of 80 square miles. The largest is lake Koshkonong, about 23 square miles in extent, and then the two beautiful lakes Mendota and Monona, adjacent to Madison, the capital of the state, and having a combined area of about the same amount. Lake Horicon, when it existed, had an area of about 50 square miles, but is now drained down to a marsh and mud lake. Mention should also be made of Beaver Dam lake, about 7 miles long and three-quarters of a mile wide, formed by an artificial dam. The four Madison lakes drain into the Catfish. Beaver Dam lake is tributary to Beaver Dam river, and so to the Crawfish river. Lake Koshkonong is an expansion of the Rock river, about 10 miles long and 2 miles wide, with its foot 6 miles above the mouth of Catfish river.

These lakes exert an important effect upon the flow of the main river, especially lake Koshkonong, which has a dam at its outlet and is controlled in the interests of the water-powers below. To them is very largely due the maintenance of flow in dry and severely cold seasons.

Artificial reservoirs.—There is no physical difficulty in the way of greatly increasing the steadiness of the river by means of storage in Wisconsin, and this region has been considered in connection with river basins northward for an application of the reservoir system. The manufacturers are desirous that the government should include the river among the reservoir streams of the upper Mississippi, and point to the old basin of lake Horicon as an excellent reservoir site.

Mr. Joseph P. Frizell, assistant engineer to Major Charles J. Allen, stationed at Saint Paul in charge of the reservoir system, has made calculations with reference to the practicability of this scheme, and arrives at conclusions adverse to the undertaking of the work by the United States.

Assuming that a complete system of reservoirs were established in the basin in Wisconsin, and that all the flow from these were concentrated within one hundred days of low water in the summer, it would give a discharge of 5,787 cubic feet per second, an amount which would add appreciably to the low-water volume of the Mississippi at Rock Island, and would cause a rise of about 6 inches above low-water stage at Des Moines rapids. It is probable that such reservoirs could be constructed, but the expense would be very great for land damages, and also for the interference with the water-powers.

By renewing the dam and reforming lake Horicon there can be a discharge of 600 cubic feet per second added to the low-water discharge of the river for a period of 120 days. This would be of great value to the water-powers along the river, but would be of no practical value in the Mississippi below Rock Island, where the extreme low-water flow is 19,000 cubic feet per second.

A dam 200 feet long would raise the water 10 feet high, and the expense would be very little, but Mr. Frizell estimates that the land damages would probably amount to from $200,000 to $300,000.

It is very easy to see that the reservoir system, so far as the government promotes it, must be limited in its application to the wild lands of northern Wisconsin and Minnesota, at least until navigation upon the side streams is to be considered; and with regard to the Rock river, it is pretty safe to say that whatever is done further in the way of impounding the surplus water will be done for and by the growing water-power interests along the stream.

Lake Koshkonong.—The only body of water now controlled in the interests of the manufacturers is lake Koshkonong. There is a dam at Indian ford, 4 miles below the real foot of the lake. The total cost of the dam, land damages, etc., was $30,000, and was borne by the following water-powers in the proportions given: Janesville, 29.5 per cent.; Rockton, 16 per cent.; Beloit, 29.5 per cent.; Rockford, 25 per cent.

The lake can be drawn down 5 feet, through 40 feet of gate opening. The aim is to keep the lake full until low water in the river. In the lowest water there has not been taken from it an amount greater than 15 per cent. of the corresponding volume of the river, according to account. Ordinarily the supply is sufficient to last through the low water, but in the winter of 1880–'81 there was a steady draught upon it from September to January, and the lake was drained very low. For five years previously there had been no serious difficulty from low water.

The capacity of the lake could be very largely increased, and Mr. Frizell states that "there is no physical obstacle to the erection of a dam 20 feet high, but it would involve very heavy damages, greatly extending the area of the lake, and flowing out mill privileges above".

The expense of increasing upon an extensive scale the storage capacity of Rock River basin is seen to be very great, and doubtless deters the manufacturers from an extensive system of improvement. This expense will increase with the value of land, but the manufacturing interests are also destined to develop, and as the necessity is more and more felt for a greater stability of flow, there is reason to believe that the capital invested will warrant the extensive storage of water, perhaps such as is found upon some of New England's manufacturing streams.

There is this disadvantage: that the surface is not mountainous, and hence the tendency is for reservoirs to be broad and shallow instead of deep; thus extensive tracts are overflowed, and generally these will consist of valuable land.

Table of fall, drainage areas, flow, etc., of the Rock river.

Locality.	Distance from source.	Distance from preceding station.	Fall from source.	Fall from preceding station.	Drainage area above station.	Flow per second past station in cubic feet.		Theoretical power under 10 feet head.	
						Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Miles.*	*Feet.*	*Feet.*	*Sq. miles.*	*Cubic feet.*	*Cubic feet.*	*H. P.*	*H. P.*
Utmost source									
Former outlet of lake Horicon	25	25	20	20	497	179	450	203	511
Above mouth of Crawfish river	80	55	93	73	1,102	397	998	450	1,132
Mouth of Crawfish river	80	0	93	0	1,899	684	1,720	776	1,951
Fort Atkinson	87	7	97	4	2,290	824	2,075	935	2,354
Above mouth of Catfish river	105	18	108	11	2,615	952	2,396	1,080	2,718
Mouth of Catfish river	105	0	108	0	3,175	1,143	2,877	1,297	3,264
Above mouth of Pecatonica river	135	30	165	37	3,795	1,366	3,438	1,550	3,900
Mouth of Pecatonica river	135	0	165	0	6,403	2,305	5,801	2,615	6,581
Above mouth of Kishwaukee river	160	25	189	24	6,703	2,413	6,073	2,738	6,890
Mouth of Kishwaukee river	160	0	189	0	7,970	2,869	7,221	3,255	8,192
Mouth of Leaf river	173	13	212	23	8,476	3,051	7,679	3,461	8,712
Above mouth of Elkhorn creek	221	48	280	68	8,915	3,209	8,077	3,641	9,163
Mouth of Elkhorn creek	221	0	280	0	9,175	3,303	8,313	3,747	9,431
Above mouth of Rock creek	250	29	307	27	9,330	3,359	8,453	3,811	9,590
Mouth of Rock creek	250	0	307	0	9,543	3,435	8,646	3,897	9,809
Above mouth of Green river	274	24	325	18	9,680	3,485	8,770	3,954	9,950
Mouth of Green river	274	0	325	0	10,811	3,892	9,795	4,415	11,112
Mouth of Rock river	286	12	340	15	10,973	3,950	9,942	4,481	11,279

Table of the tributaries of the Rock river.

River.	Length.	Drainage area.	Discharge per second.		Theoretical power under 10 feet head.	
			Ordinary low flow.	Average flow.	Ordinary low flow.	Average flow.
	Miles.	*Sq. miles.*	*Cubic feet.*	*Cubic feet.*	*H. P.*	*H. P.*
Crawfish river	60	798	287	723	326	820
Catfish river	40	530	191	480	217	545
Pecatonica river	140	2,608	939	2,363	1,065	2,681
Kishwaukee river	50	1,260	456	1,147	517	1,301
Elkhorn creek	40	261	94	236	107	268
Rock creek	45	213	77	193	87	219
Green river	80	1,131	407	1,025	462	1,163

DESCRIPTION OF THE WATER-POWERS.

Taking the water-powers in their order of occurrence from the source to the Mississippi river, the characteristic features of each are as follows, naming also known undeveloped sites:

From the source to Watertown.—On a branch of the river which flows from the west in Washington county, there is a small saw-mill using about 8 horse-power under a head of 12 feet, but with that exception there is no utilized power which can be considered to be situated on the Rock river until Hustisford is reached, 10 miles below the village of Horicon, which is at the old outlet of lake Horicon.

Hustisford.—At Hustisford there are two grist-mills and a saw-mill. In the census returns the grist-mills are rated as using 65 and 90 horse-power under heads of 8 and 7 feet, respectively, and the saw-mill is rated as using 35 horse-power under a head of 13 feet. These are probably greater than the true amounts, as the grist-mills have only two or three runs each.

Second power.—The next utilized power is 22 miles below Hustisford and 5 miles above Watertown, where there is a mill with three runs of stones under a head of 4 to 6 feet, and at Watertown a small saw-mill, which, however, does not appear in the census returns.

Third power.—The next and last power used above Watertown is 1 mile above that place, and is taken by a four-run mill, working under a head of 6 or 7 feet, and probably using 50 or 60 horse-power. All these powers and the remaining three above lake Koshkonong have the disadvantage not experienced by the other water-powers below, of having no artificially-regulated reservoir, and hence must depend largely upon the natural storage of the Horicon swamp for the maintenance of the flow.